Vol. XLIX

TABLE OF CONTENTS.

No. 24

(24 pages; no inset.)

Page

ENGINEERING NEWS OF THE WEEK 513

LEADING ARTICLES:

The New York Rapid Transit Railway. XXI. Contract Sections XIII. and XIV. 514

Burning Illinois Coal Without Smoke. ..... L. P. Breckenridge, M. Am. Soc. M. E. 519

Tests of the Efficiency of Hoisting Tackle (illustrated). ..... S. L. Wonson 520

Some Tests of Boiler and Furnace Efficiencies (illustrated). ..... A. Bement 521

Irrigation Studies in the Humid Sections of the United States. 523

Instructions to Inspectors of Cast-Iron Water Pipe, Special Castings and Stop Valves, Philadelphia. 527

Steel Sheet Piling (illustrated). 528

Some Practical Suggestions Concerning the Genesis of Ore Deposits. ..... Max Boehmer, M. Am. Inst. M. E. 528

The Stresses on Skew Arches (illustrated). ..... W. C. Kernot, M. Am. Soc. C. E. 529

Reinforced Concrete Bridge Over River Des Peres, Forest Park, St. Louis, Mo. (illustrated). 530

Malleable Cast-Iron. ..... Dr. Richard Moldenke 531

The Development of the Commerce of the Great Lakes. ..... Alfred Noble, Pres. Am. Soc. C. E. 532

A Small Municipal Water and Electric Light Plant at Tullahoma, Tenn. 536

Accidents Due to Combustion Within Air Compressors. ..... W. L. Saunders, M. Am. Soc. C. E. 536

EDITORIAL COMMENT.—An Example of Translation from the German—The Definition of Civil Engineer and Civil Engineering. 524

EDITORIAL.—The Design and Cost of Slope Walls, Including Cost of Quarrying (illustrated). 524

LETTERS TO THE EDITOR.—The Engineering Building of America: One more Impression of the Situation: Clemens Herschel, M. Am. Soc. C. E.—The Union Engineering Building: John C. Wait—Right and Left in Structural Work: "Draftsman."—Proposed Steel Dam. Irrigation Reclamation Service, U. S. Geological Survey (illustrated): Chas. R. Steiner. 526

IRRIGATION IN THE EASTERN UNITED STATES has led to a number of interesting devices for applying water to the crops. The Hittinger Fruit Co., of Belmont, Mass., says Mr. Bristow Adams in "Forestry and Irrigation" for June,

makes use of a special and very simple apparatus, and one that is valuable where there are inequalities in the surface of the ground, for by its use the expense of leveling and grading can be done away with. The water supply is obtained from one of the Boston city reservoirs, and comes under a pressure of 25 lbs. per sq. in. In the center of each quarter acre there is a firmly planted post, 6 ins. square and about 7 ft. high. On top of this post is pivoted a 20-ft. beam. A 2-in. pipe runs from a main pipe to the top of the post, where it divides to form two 10-ft. arms, to the ends of which are coupled about 20 ft. of garden hose, terminating in an ordinary nozzle. As the whole apparatus revolves, it can be seen that one man, with a force of water which will throw a stream from 30 to 40 ft., can effectually irrigate nearly half an acre, and can so regulate the supply as to suit the needs of a crop under any condition or stage of growth.

At Vineland, N. J., a gardener

uses a large supply pipe along one side of the fields to be irrigated, and at intervals along its length are lateral pipes with couplings and valves, to which a section of rubber hose is attached, and this in turn is connected with a long pipe which extends across the field, supported on wooden disks or wheels at intervals of about 12 ft. Starting at one end of the tract to be irrigated, the long lateral pipe is connected with the supply pipe at the side of the field by means of the rubber hose, and as the ground is watered the pipe is pushed along on the wheels to the limit of the hose, when it is uncoupled and attached to the next lateral vent, and so on until the whole area is watered. The advantages claimed for this device are: that the water, by means of the sprinklers placed at intervals on the lateral pipes, can be regulated to the needs of different parts of the ground and crop; that there are no permanent fixtures in the field itself to interfere with thorough cultivation or to take up any room from the crops. The rows or furrows of the field are run the same way that the large wheels progress, so that there is no crushing of the crop, the wheels being made to run in the furrows or between the rows.

CONSOLIDATING AN EMBANKMENT BY FLOODING was tried in 1902 by the Metropolitan Water and Sewerage Board, at the north dike of the Wachusett reservoir, at Clinton, Mass. The work is described as follows by Mr. Hiram A. Miller, M. Am. Soc. C. E., Engineer Reservoir Department, in the report of the board for 1902:

A day-labor force was engaged most of the time during the first half of the year in consolidating the soil in the dike by saturating it with water, continuing the work which was in progress at the end of the previous year. Water was pumped day and night from Sandy Pond upon the easterly portion of the dike, from the beginning of the year until March 22, and from May 19 until June 30. Special care was taken during the first period of pumping to saturate the soil rolled in 6-in. layers, and the embankment to the extent of 4½ acres was flooded for about twelve weeks. This required the construction of about 6,050 lin. ft. of small dikes, from 1 to 6 ft. in height, forming small basins into which the water could be pumped. During the second period of pumping the water was used entirely on the northerly slope of the dike. The amount of water pumped upon the easterly portion of the dike was approximately 68,000,000 gallons. Water was pumped upon the westerly portion of the dike during the day time from Feb. 24 to May 19, except when the pump was out of service for needed repairs.

Measurements made to determine the extent to which the soil was consolidated by the saturation indicated that it had already been so well consolidated that the saturation did not have any large effect. On the portions of the embankment where the soil had been rolled in 6-in. layers and it had an average depth of 51 ft., the settlement, as shown by measurements at 22 points, ranged from 0.06 to 0.26 ft., and averaged 0.15 ft. On the portions of the embankment where the material had been deposited in 7½-ft. layers without rolling and it had an average depth of 40 ft., the maximum settlement, as shown by measurements at 186 points, was 1 ft., and the average settlement 0.47 ft.

EXPERIMENTAL MEASURES TO PREVENT ELECtrolysis of water mains were taken by the Boston Elevated Ry. Co. in 1902, with the co-operation and advice of the Metropolitan Water and Sewerage Board. Three sections of 48-in. main, in the vicinity of the North Harvard St. power station, were chosen. One section was 26 ft. long and was opposite the power house; another, 77 ft. long, was crossed by three tracks entering a car house; the third, 39 ft. in length, was under two tracks, at a curve. The treatment is described as follows in the report of the board for 1902:

The pipes were first thoroughly cleaned with scrapers and wire brushes. A coat of asphalt paint was then applied, and over this a layer of Warren's "Kiola rock asphalt wire composition" was applied hot. A sheet of burlap was then wrapped around the pipe, and over this another layer of the hot asphalt was put on. The insulation was applied in short sections, which overlapped about 6 ins. at the junction lines, and when completed was from ¼ to ½-in. in thickness. As the trench was refilled, three lines of old tram rails were laid in the trench parallel with the axes of the pipes, and about 6 ins. from the bells at the nearest point. These rails were connected to the pipe line by means of "0000" copper bonds soldered to the pipe bells near the ends of each insulated section. The rails were also connected at the ends with similar copper bonds. Where the pipe line was located under the car tracks, the rails were placed in a horizontal plane directly over the pipes, and opposite the power station where there are no tracks in the street they were placed in a vertical plane. Arrangements have been made so that the amount of electricity flowing off from the rails can be measured, and also the amount flowing on the pipes. All of the pipes insulated showed the effects of the electrolytic action, and some of them had been very badly damaged. Careful measurements and plaster of Paris impressions of many of the pittings were made, for future reference. On one pipe there were about 80 pittings, varying in size from circles ¾-in. in diameter to bands 30 ins. long by 1 in. to 1½ ins. in width, and from 1-16 to 9-16-in. in depth.

THE CONSOLIDATION OF THE BOSTON GAS INterests is expected. Steps to this end are the appointment of a receiver for the Bay State Gas Co. of Delaware, sometimes known as the Addicks Company, and the practically unanimous passage of a bill by the lower branch of the Massachusetts legislature authorizing the companies in interest to consolidate. Consolidation had been recommended by the States Gas and Electric Light Commission and by the State Board of Trade.

THE CAIRO BRIDGE of the Illinois Central R. R. over the Ohio River at Cairo, Ill., is a single-track structure with long approaches, and in view of the very heavy traffic the approaches are to be double-tracked from the end of the present earth embankments (which are already double-tracked) up to the 250-ft. spans at each end of the main bridge. There will remain about 4,000 ft. of bridge, which is not to be double-tracked at present. The work now proposed is the construction of an earth embankment on the Illinois side to replace seventeen deck spans of 150 ft. and one of 106 ft. On the Kentucky side it is intended to build a double-track embankment in place of nine deck spans of 150 ft. and one of 106 ft.; all the original deck spans will then be combined for carrying the double track of the twelve remaining spans on the Kentucky side. Contracts for part of the work have been let, and other parts are not yet under contract, while a portion of the work will be done by the railway company.

NEW FOUNDATIONS UNDER OLD BUILDINGS are a feature of some of the important building construction now in progress in Chicago. In the business district a number of buildings are to be torn down and replaced by office or store buildings of steel frame construction, and in order to reduce the loss of rental to a minimum, the foundation work for the new building (which is often the slowest part of the work) is done before the old building is vacated. The basement or cellar is given up to the contractor, and sidewalk chutes or cellar openings are used for delivering materials, while the building and sidewalk are supported by shoring and underpinning where the original supports have to be removed. The caissons are then sunk or other work carried out before the leases of tenants expire. When the old building is vacated it takes very little time to demolish it and clear the site, and the construction of the new building can then be commenced at once upon the foundations built in advance.

A CAR LOAD OF DYNAMITE and powder exploded June 7 at Tecolotes, Mexico, killing six men and blowing up a whole train. A spark from the locomotive is believed to have caused the accident.

FLOOD HAVOC FROM A CLOUDBURST is reported from the northwestern part of [redacted] Carolina. It is estimated that about one hundred [redacted] were lost and a vast amount of property loss produced, chiefly by the destruction of a number of cotton mills. Exceedingly heavy rains prevailed in the mountain district of southwestern North Caroline and on the piedmont plain of the extreme northwestern portion of South Carolina during two or three days preceding June 6. On the morning of that day a terrific rainstorm, centering around Spartanburg, S. C., sent a sudden flood down the swollen streams flowing to the southeast in that district. The flood did damage along a number of streams, but seems to have caused the largest losses in the valley of the Pacolet River, where several important mill towns are situated. At Pacolet two large cotton mills were destroyed; at Clifton three mills were wholly or partly swept away, and lesser damage is reported from several other places in that neighborhood. The loss of life occurred principally among the mill workers, who had no warning of the sudden flood.

THE MOST SERIOUS RAILWAY ACCIDENT of the week occurred on the Missouri Pacific Ry. near Stillwell, Kan., on June 4. The Atchison, Topeka & Santa Fe Ry., whose tracks were blocked by washouts due to the flood, was running over the Missouri Pacific tracks south of Kansas City; two Santa Fe passenger trains on this part of the line collided head-on, one of the trains having run past the meeting point named in the train orders. Nine persons, most of them passengers, were killed in the wreck and many others were injured.——Another unusually bad accident, which occurred on the Atlantic Coast Line R. R. near Wedgefield, a short distance west of Sumter, S. C., on June 3, was due to the rains and floods in that region. A crowded passenger train ran into a washout and was completely wrecked. Five lives were lost.

THE FLOODS IN THE MISSISSIPPI VALLEY, noted in our last issue, now center about the city of St. Louis, where it appears that a flood stage exceeding the record for the past fifty years will be reached. The towns of Granite City, Madison and Venice, Ill., opposite St. Louis, are all under water through the breaking of the Madison levee; East St. Louis, Ill., is as yet only partly flooded, but the levee protecting the remainder of East St. Louis may break. In St. Louis itself the damage will not be as heavy as at other points, as the larger part of the city is on high land, and before the lower portions were flooded there was time to remove all valuable property. The flood at Kansas City, Mo., is slowly receding, and the work of clearing up is in progress.

ATLAS SHEETS of the Newburg (N. Y.), the Hammondsport (N. Y.) and the Winthrop (Iowa) Quadrangle are ready for distribution by the Director of U. S. Geological Survey. The contour interval on each sheet is 20 ft.

THE RECENT ACCIDENT TO THE "MAINE," when during target practice it was found that the turret supports and the gun foundations generally were so weak as to be seriously damaged by the shock of firing, will probably dictate changes in the battleships and cruisers now building for the United States government. The gun foundations on all the vessels in process of construction are to be strengthened considerably to meet the high power, and consequent heavy recoil, of the present day naval ordnance.

BIDS FOR 16,000-TON BATTLESHIPS, three of which were authorized by the last Congress, were opened in Washington during the past week. The lowest bids and specified terms of completion are the following: Newport News Shipbuilding Co., Newport News, Va., one vessel to the plans of the Navy Department, $4,110,000, the vessel to be completed in 42 months; New York Shipbuilding Co., Camden, N. J., one vessel to the plans of the Navy Department, $4,165,000, time 42 months; Fore River Ship & Engine Building Co., Quincy, Mass., one vessel to the plans of the Navy Department, $4,179,000, time 42 months. Two other bids were received, the Eastern Shipbuilding Co. of New London, Conn., bidding $4,192,000, time 42 months, and the Wm. Cramp & Sons Ship & Engine Building Co. of Philadelphia, Pa., bidding $4,190,000 for one vessel, or $4,181,000 each for two vessels, time 42 months.

THE NEW YORK RAPID TRANSIT RAILWAY.*

XXI.

Contract Sections XIII. and XIV.

Sections XIII. and XIV. of the Rapid Transit Railway were awarded to the same subcontractors, L. B. McCabe & Bro., of Baltimore, Md.; they abandoned the work in March, 1903, and the sections were completed by the general contractor, Mr. John B. McDonald. The methods of work employed were the same on both sections and they will, therefore, be described together. Briefly defined, Section XIII. extended from 133d St. to a point 100 ft. north of 181st St., and Section XIV. continued the line from the latter point to Hillside Ave., at Fort George. The notable feature of these two sections was that 11,482 ft., or some 2 1-5 miles, of the work was deep tunnel in rock.

FIG. 119. VIEW SHOWING APPROACH TO NORTH END OF MANHATTAN VALLEY VIADUCT AT 133D ST.

SUBWAY STRUCTURE.—From 133d to 134th streets, the north approach to the Manhattan Valley viaduct, the structure is elevated above street surface, and consists of an earth fill between granite and brick retaining walls, with an abutment at the north building line of 133d St., at which point the base of rail is 13 ft. above street surface (Fig. 119). At the south side of 134th St. the rails will be practically at street grade, and descending at a grade of 2.02%, reach the portal of the steel and concrete structure at 135th St. The portion of the approach between 134th and 135th streets is open cut with brick and concrete retaining walls surmounted by ornamental granite paneling.

Beginning at 135th St. the subway structure is the standard three-track steel and concrete construction to the south end of the station at 137th St. The station structure then comes in, and is followed by the underground storage yard mentioned in describing the work of Section XI. This storage yard extends in length to the south end of the station at 145th St., and is formed by widening out the standard structure from both sides so as to accommodate altogether eight parallel tracks. These tracks are designed to serve normally as storage tracks for cars, and they will afford room for 150 standing cars, but it will be possible of course to use when needful at least one of them for running express trains. Following the storage yard comes the 145th St. station construction, and then two-track steel and concrete construction to a point about 100 ft. south of 147th St. At the last point double-track concrete tunnel construction begins and continues in open cut to a point 28 ft. south of 151st St., then in tunnel to a point 55 ft. south of the north side of 155th St., then again in open cut to a point 9½ ft. north of the north side of 158th St., and thence in tunnel to the end of Section XIV., at Ft. George. At 157th St. there intervenes a station of standard steel and concrete construction, and at 168th and 181st streets two stations formed by 50-ft. concrete arch spans built in tunnel. The two-track tunnel arch used is of the standard form and dimensions used elsewhere on the road, as, for example, on Section VII.; that is, it has an invert, vertical sidewalls 25 ft. apart, and a semicircular roof arch of 12½ ft. radius. The tracks follow a rolling grade never over 1%, except as above noted, and for the short approaches on each side of the 168th St. and 181st St. stations, which are 1% and 1.5% on the south and north sides respectively, and for the long grade of 1.09% between 138th and 145th streets.

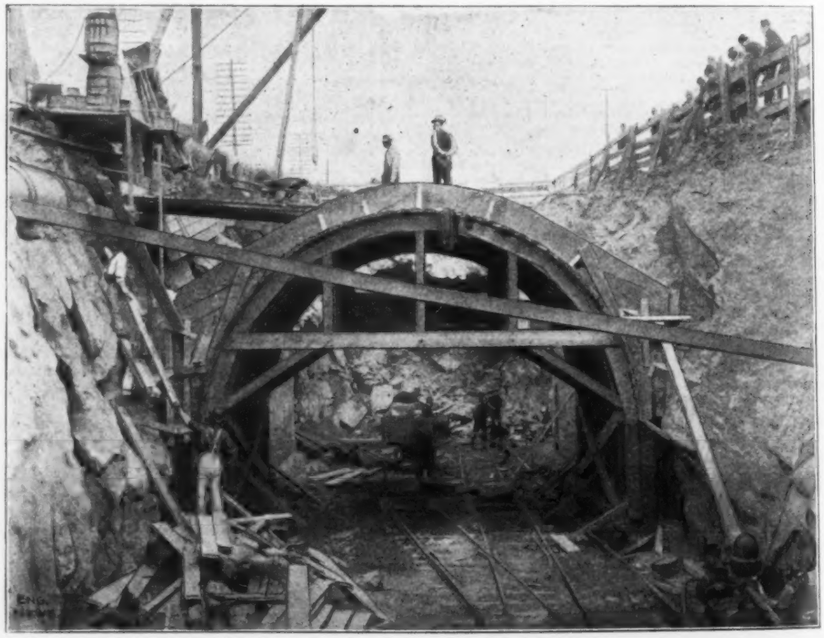

FIG. 120. VIEW SHOWING CONSTRUCTION OF CONCRETE ARCH IN OPEN CUT.

MATERIALS PENETRATED.—In plan the subway of Sections XIII. and XIV. follows Broadway throughout their entire length. Beginning at 135th St., the depth of the subway below the surface is quite small, and the material penetrated consists of sand and loam with some rock until 145th St. is approached. At about 150th St. there begins a sharp rise in the street surface which reaches its summit at 153d St., where base of rail is 56 ft. below street surface, and then drops gradually to a low point at 157th St. This hill is of rock formation, generally solid and tough mica-schist. Just north of 157th St. the surface begins again to rise rapidly and keeps high above the subway until the sharp drop of the cliff at Ft. George terminates the underground portion of the West Side Line at the end of Section XIV. At the highest point at 190th St. the base of rail is 200 ft. below street surface. Like the hill to the south of 157th St., this ridge is of mica-schist rock, mostly solid and tough.

METHODS OF WORK.—For convenience in describing the methods of work on Sections XIII. and XIV. of the Rapid Transit Railway, they will be divided into two parts, one part including all the open-cut work and the other part including all the tunnel work.

OPEN-CUT WORK.—As already stated, there were two stretches of the subway of Sections XIII. and XIV., which were built in open cut. The first of these sections included the stretch of work between 134th and 151st streets, and the second was the short stretch on each side of 157th St.

It was originally intended that the West Side Line should be double-track structure throughout; but as stated in a previous article the original plans were subsequently changed so as to provide for an eight-track storage yard between 138th and 144th streets, and a three-track line from this yard to 104th St. Work north from 134th St. was begun and completed for some distance on the original plans so that when the change in plans was made this work had to be rebuilt, as described in a succeeding paragraph. Neglecting for the present this work of reconstruction, the method of work followed throughout the open cut south of 151st St. was as follows: From 134th St. north to the south end of the 137th St. station a single trench wide enough for two tracks was first excavated and the subway structure built within the excavation. The station structure at 137th St. and the underground yard structure north of the station were designed to be of the regluar steel bent and concrete wall and roof type of construction, but owing to cross-overs into storage yard the roof beams range in depth from 15 ins. to 54 ins. Since, however, these structures occupied the whole width of Broadway, it was impossible to open up the full

*The preceding articles of this series have appeared in Engineering News of the following dates: 1902, Jan. 30; Feb. 6, 14, 20; March 6, 20; April 17; May 8; Sept. 18, 25; Oct. 2, 23; Nov. 13; Dec. 4; 1903, Jan. 1; Feb. 12; Feb. 19.

width of excavation necessary for them at one time, for the reason that it would close the street entirely to traffic. The contractors, therefore, opened a trench from the center line of the street to the outer limit of excavation on the west side and built one-half of the structure within it. This portion of the work was then back-filled and the

Fig. 121. View Showing Arrangement of Screw Jacks for Moving Concrete Wall.

street restored to traffic, and afterwards the other half of the excavation was opened up, and the second half of the subway built within it and properly connected to the half which was built first. A similar procedure was employed in building the 145th St. station structure. North from the 145th St. station to the beginning of the tunnel at 151st St., the open-cut work was for double-track structure only, part of it being two-track steel and concrete subway and part double-track concrete arch construction. A trench was opened for the full width of the structure, and the steel bents and concrete arch erected within it. To erect the concrete arch structure the floor or invert was first built on the bottom of the trench. Sidewall molds were then placed on the invert and the vertical sidewalls built up to 13 ins. above the springing lines of the roof arch. To build the roof arch a center, of the form shown by Fig. 120, was erected. The view given illustrates the construction of the center and the arrangement of the concrete mixer and other appliances very clearly.

The disposition of the excavated material was accomplished by dump cars running on 30-in. gage tracks laid in the bottom of the excavation and along its edge, and leading to a cable incline at 144th St. This cable incline was of the balance rope type, in which the descending loaded car attached to one end of a rope hoisted the ascending empty car attached to the other end, the rate of travel being controlled by a band brake on the winding drum. From the foot of the incline the tracks led to dumping grounds purchased by the contractors. To get the cars to the top of the incline locomotives and mules were employed. It should perhaps be stated in concluding this reference to the open-cut work south of 151st St., that considerable use was made of a land dredge of the orange-peel type to take out the soft material, particularly where the wide excavation for the storage yards had to be made.

The short stretch of open-cut work north and south of 157th St. calls for brief mention only. A single wide trench was opened up through the earth and rock until the necessary faces were obtained for the portals of the tunnel sections beginning at each end. Derricks and cars were used for handling the spoil, which was taken to a dump at 162d St. and Lafayette Boulevard.

WIDENING THE TWO-TRACK STRUCTURE.—Mention was made above of the necessity of widening the double-track structure built previous to the change of plans calling for three tracks for the lower portion of the West Side Line. Altogether about 475 ft. of two-track structure had been built between 134th St. and 137th St. when the change was ordered; of this 200 ft. were approach structure between retaining walls and 275 ft. were steel and concrete subway structure which followed this approach. To provide for the additional tracks the sidewalls of the approach had to be thrown 11 ft. further apart and the subway structure widened 11½ ft. by inserting that width of steel and concrete roof.

The method proposed was to move back each of the brick-faced concrete retaining walls of the open-cut approach and set them on new foundations, and for the subway portion, to move the roof and one sidewall one way and the remaining sidewall the other way, and to set them on new foundations, and, finally, to fill in the gap in the roof.

The portion of the work which was first attempted was the moving of the approach walls. These walls were each 200 ft. long, and ranged in height from 3 ft. to 14 ft. In side elevation they were wedge-shaped, since their bottoms followed the descending grade of the approach track and their tops rose on an ascending grade to the roof of the subway. The walls varied from 3 ft. to 7.5 ft. in width on the bottom, and were 2½ ft. wide throughout on the top. The faces of the walls were vertical, and their backs were stepped. Under each wall and extending clear across the bottom of the approach cut there was a concrete footing about 14 ins. thick.

The method adopted for moving the walls to their new location was as follows: The concrete footing or floor was cut through by a trench about 30 ins. wide parallel to each wall and close to its vertical face. The ground was then excavated back of the walls so as to give the increased width of cut. From the back of each wall 12 × 12-in. timbers were then thrust endwise under the footing. These timbers were just long enough in each case to project slightly beyond the front and rear faces of the footing. From their rear ends concrete ways or walls were carried back to and beyond the foundation site of the wall when in its new location. Lengthwise of the 12 × 12-in. timbers were placed 5 × ½-in. strips of steel long enough to reach the full length of the concrete ways. By means of wedges and blocking the 12 × 12-in. timbers were raised a sufficient height to carry the wall clear of its foundation bed. When in this position the top of each 12 × 12-in. beam was just flush with the top of its corresponding concrete way, and by means of the steel strip a perfectly level and continuous track therefore existed from the front face of the old wall to the rear face of the new foundation. Upon these parallel tracks the wall was to be slid into its new position. To give the wall a smooth bearing on the tracks, steel plates were embedded in the concrete footing so as to bear upon the track strips. A new footing for the wall was then constructed in the spaces between the concrete ways, but its top was kept a few inches below the tops of the ways so that any irregularities on the bottom of the wall would clear the new footing when the wall was being slid into position over it. Afterwards these spaces were filled in with heavy gravel grout. The track timbers and the concrete ways were spaced at distances apart varying from 3 ft. at the highest part of the wall to about 6 ft. at the lowest part. Altogether 37 ways were used for each wall. The actual moving of the wall was accomplished by means of screw jacks. Thirty-four of these were used for each wall, and they were placed in a trench cut in the approach floor at points exactly opposite the track ways, Fig. 121, except at the south end, where the wall was small and the jacks were spaced further apart. The feet of the jacks abutted against the concrete floor and their heads against the wall. As the jacks were extended and the wall moved backward they were followed up with blocking. By means of these jacks the wall was pushed gradually to its proper position. Neither wall was seriously cracked or injured during the moving process.

The second part of the work was the widening of the concrete and steel subway structure. This structure was about 275 ft. long, and was made up of steel bents spaced 5 ft. apart and filled in with concrete, as shown by Figs. 122, 123 and 124. It will be noted that an interior row of columns separated the two tracks. The foot of each wall column and of each interior column was secured to the concrete column foundation by anchor bolts.

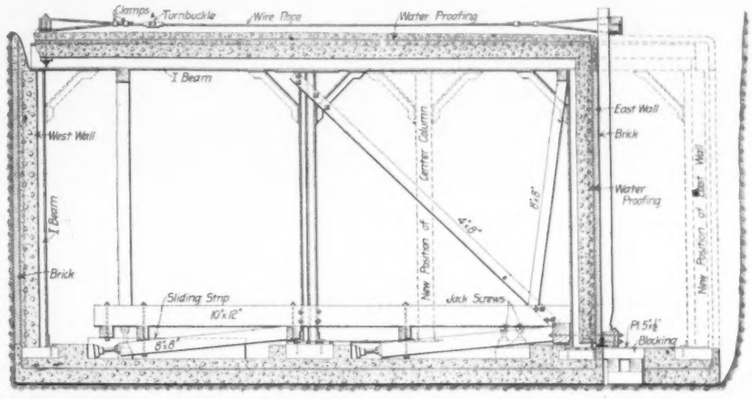

FIG. 122. SKETCH SHOWING ARRANGEMENT OF BRACING AND JACKS FOR MOVING EAST WALL AND ROOF.

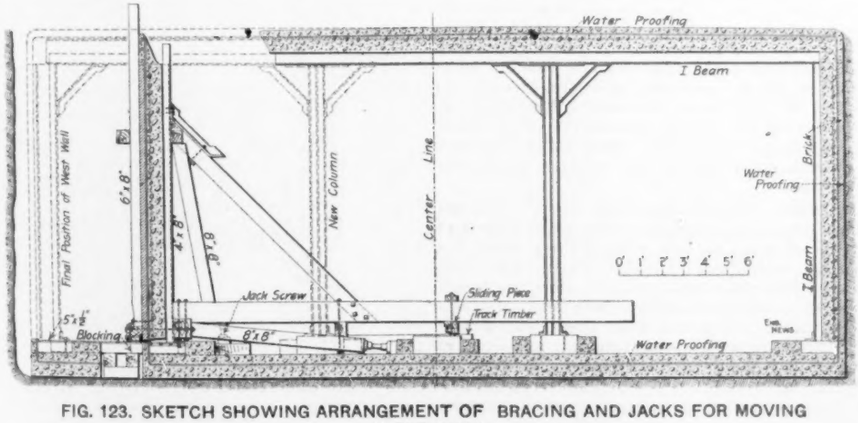

FIG. 123. SKETCH SHOWING ARRANGEMENT OF BRACING AND JACKS FOR MOVING WEST WALL.

Around the whole structure, as is shown by the illustrations, a layer of water-proofing made of asphalt felt and asphalt was placed. On the sidewalls this water-proofing was held in position by a wall made of a single course of bricks held in place by the earth filling.

To widen the structure described, the roof was cut away from the top of the west wall, as shown by the illustrations, and the roof, east wall and center columns were moved in one piece a distance of 6 ft. to the east, while the west wall in one piece was moved 5½ ft. to the west. This left a gap of 11½ ft. in the roof. To close this a second row of interior columns was erected, and I-beam roof beams were inserted to complete the four-column bent called for by three-track construction. The estimated total weight of the east wall and roof was about 3,000,000 lbs., and the west wall, which was about 2 ft. thick and 15 ft. high, weighed about 700,000 lbs. So that the structure would not be injured or distorted by the masonry, it was braced as shown by the illustrations. Along the outside and inside of the sidewall of the structure continuous longitudinal timbers were laid and bolted together through the wall. Cross timbers and diagonal bracing, as shown, were put in at every alternate bent, or 10 ft. apart. To support the brick wall forming the protection for the water-proofing, the outside longitudinal timber had an angle bolted to it having one leg extended under the brick, and small angle legs were bolted to the top to hold the foot of a vertical timber, which was held at the top by a continuous longitudinal timber secured by wire ropes, as shown. These vertical sticks on the outside were spaced 10 ft. apart. The anchor bolts, which secured the feet of the several columns, were cut off flush with the top of the bed plates. Jack screws were then arranged under the east side of the roof, as shown, and the latter was raised sufficiently to lift the center line of columns, so that the base plate was clear of the bolts. Sliding strips of 5 × ½-in. iron were then placed under the bed plates and blocked up so that the bed plates would pass over the bolts. The jack screws were then moved under the west side of the roof, as shown, and the west wall and columns were similarly raised. Slideways were then made of timber blocking to carry the structure to its new location, and the jacks were placed in horizontal positions, as shown About 50 jack screws were used. The moving of the west wall was accomplished in exactly the same manner as the east wall was moved, except for such differences as are obvious from the drawings.

FIG. 124. VIEW SHOWING EAST WALL AND ROOF MOVED AND WEST WALL READY TO MOVE.

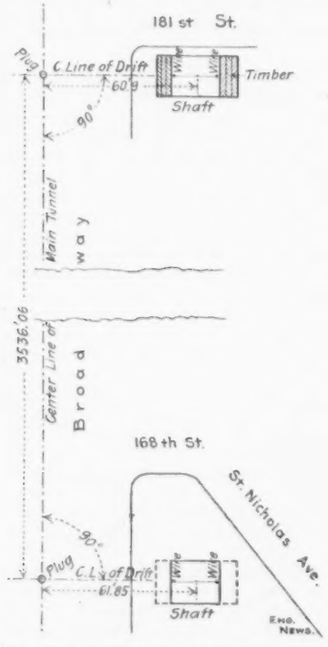

Fig. 125. Sketch Illustrating Surface Surveys for Tunnel Alinement.

TUNNEL WORK.—The first length of tunnel work was that under the hill between 151st and 155th streets. It was built entirely from the portals, which were 1,112 ft. apart. This was followed by the short open-cut section previously described, and then came the long Fort Washington Tunnel, nearly two miles long. This tunnel was built from portals at 158th St. and at Fort George, and from two shafts located at 168th St. and at 181st St. It is worth mention in passing that this is one of the longest rock tunnels which has been built in the United States in recent years. The dates of beginning work at the several portals and shafts of the two tunnels were as follows: 151st St., portal north, Jan. 18, 1902, 155th St., portal south, July 12, 1901; 158th St., portal north, Sept. 27, 1900; 168th St., shaft, July 12, 1900; 181st St. shaft, July 24, 1900; Fort George, portal south, March 15, 1902. Practically the same methods of work were employed on both tunnels, and they will not be distinguished from each other in the description of methods which follows:

TUNNEL ALINEMENT.—In the 151st-156th St. and the 158th St. tunnels the line and grade work was comparatively simple, except as regards actual conditions under which the work had to be carried on. The center line on the surface was run in from the portal at each end, and the only difficulties arose from the smoky condition of the tunnels, necessitating very short sights, and the difficulty of maintaining accessible permanent plugs.

168th-181st St. Tunnel.—This tunnel was worked from two shafts, one at 168th St. and the other at 181st St., the depths of which were 103 ft. and 126 ft., respectviley. The center of the 168th St. shaft is 61.85 ft. east of center line of main tunnel and is connected with latter by a tunnel running at right angles to it; the shaft at 181st St. is similarly located at a distance of 60.90 ft. from center line of main tunnel to center of shaft (Fig. 125). The work of alinement was accomplished as follows:

Assuming that the point at the intersection of the center line produced, of the shaft and main tunnel, has been established on the surface, the first operation on each occasion of dropping the line was to turn at this point a series of single right angles from the center line of the main tunnel. A mean was then taken of this series and several series of angles turned to the point thus selected, completing the circle for each series, thus multiplying the error. If an error existed the point was adjusted and angles turned completing circle as before, the process was continued until there was no error. Then the wires which had been previously suspended in the shaft were alined on the surface and kept alined by a transit during the whole operation of dropping wires.

Two No. 0 piano wires were used suspending 35-lb. plumb bobs in buckets of water. These wires were wound on specially constructed brass reels mounted on brass forms, one of which was fastened to the timber on each side of the shaft at the surface. The wire was pulled over a tangent screw set in the frame, and could thus be brought to line without difficulty.

The wires having been accurately alined on the surface and the distance from the center line of the main tunnel to west wire accurately measured (using spring balances and correcting for temperature), the work began in the tunnel by setting up the transit as nearly on the line of the two wires as possible and as far west of the center line of the main tunnel as possible, in this case about 18 ft., and "fudging" the instrument to get on the exact line of the two wires (Fig. 126). This was a long and tedious process, owing to the uncertain light, the comparatively short distances between the wires, and the difficulty of keeping wires absolutely steady. When the transit was

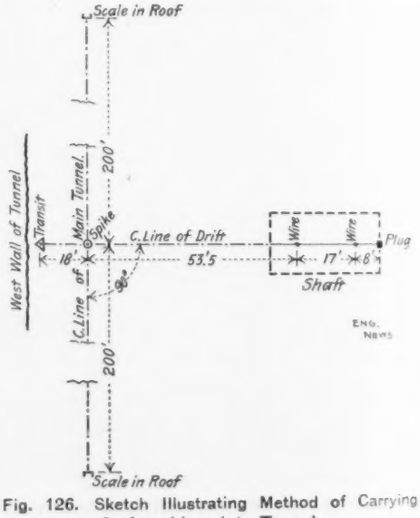

Fig. 126. Sketch Illustrating Method of Carrying Surface Lines Into Tunnel.

accurately alined with the two wires a point was at once set on a steel spike on center line of main tunnel (Fig. 126) and tested both for line and distance, and a point set on plug in east side of shaft. The wires were thrown off line and realined on surface, the transit in tunnel was moved off line and the process of "fudging" in was repeated. When the transit was again brought to line a point was set on steel spike on center line of main tunnel and a point set on plug in east side of shaft as before. A mean of the points on center spike was punched in spike and transit set up over it and sights taken on mean of two points on plug in east side of shaft and a series of right angles turned reading on graduated scales (described in Article on Section VII.), placed in roof at a distance of 200 ft. from spike at intersection of drift and main tunnel. A mean of the readings was selected and several series of right angles turned to it, completing the circle each time, and if an error existed the reading on the scale was adjusted and angles turned, completing circle as before, thus reproducing the work done on the surface.

Wires were dropped down the shafts several times and the operation described above repeated. For the final line a mean of all the points (properly weighted) on the center spike and a mean of all the readings (properly weighted) on the scales were selected, and the line run out setting points on steel spikes set in floor. Owing to the smoky condition of the tunnels the length of sights averaged 150 ft., and were not clear even at that distance, unless the illumination was extremely good. The short sights, the comparatively short distance between the wires (17 ft.) and uncertain lights were all sources of error, hence good results could only be arrived at by repetitions of all the operations by different men and taking the mean. For purposes of construction, line and grade were carried on wooden plugs set into holes drilled in the roof about 75 ft. apart.

SHAFT CONSTRUCTION.—The shafts at 168th and 181st streets were designed to be permanent, and to furnish entrances to the underground stations located at those points. Their dimensions and location were, therefore, determined by their final purpose as much as by the conditions imposed by their service as working shafts. Both shafts were, therefore, located 60 ft. east of the center line of the tunnel, and were 15 × 32 ft. in section. The 168th St. shaft was begun on July 2, 1900, and was completed to subgrade 103 ft. deep on Nov. 7, 1900, or in 101 working days. The excavation was in solid rock the whole depth, and timber was required for the first 16 ft. of depth only in order to hold securely the top ground. For the first 25 ft. in depth this shaft was excavated 15 × 20 ft. in section, but below this depth the full dimensions, 15 × 32 ft., were excavated. The 181st St. shaft was begun on July 24, 1900, and was completed to subgrade 126 ft. deep on Dec. 15, 1900, or in 131 working days. This shaft was excavated in earth for a depth of 12 ft., and in rock below that point. Timbering was employed to a depth of 27 ft., and the excavation was made the full dimensions of the section, or 15 × 32 ft. In both shafts as soon as the excavation had reached a level sufficiently below the level of the tunnel roof to permit, cross drifts from the shaft to the tunnel were started by means of top headings. These headings reached the center line of tunnel on Nov. 3, 1900, at 168th St., and on Dec. 8, 1900, at 181st St., and the tunnel headings were immediately turned north and south from them. The full size of the cross-drifts when finally completed was 25 ft. high and 29 ft. wide.

The method of timbering the shafts was one of some novelty, and is shown by Fig. 127, which is a drawing of the timbering for the 168th St. shaft. The features to be noticed are that the crib timbering in loose material at the top of the shaft is supported by heavy cross-beams extending out on each side of the shaft and the tower-like structure, which serves as a frame for the cage guides, is isolated from the perimeter of the shaft.

TUNNEL EXCAVATION.—The method of excavating the tunnel was substantially the single top heading and bench method, commonly employed in the United States in rock tunnel work. Both heading and bench were, however, broken out by an opening and a trimming cut which for convenience in description are separately indicated and numbered in Fig. 128. Altogether 40 holes were drilled and blasted in opening up the full tunnel section. Fig. 128 shows the approximate location of these holes, and after work was well in progress the order of firing them was as listed in the table below:

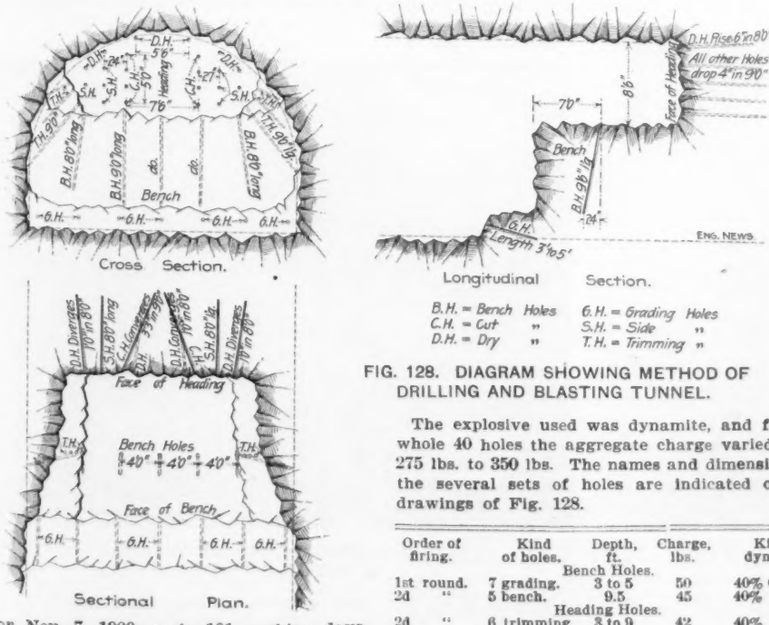

FIG. 128. DIAGRAM SHOWING METHOD OF DRILLING AND BLASTING TUNNEL.

The explosive used was dynamite, and for the whole 40 holes the aggregate charge varied from 275 lbs. to 350 lbs. The names and dimensions of the several sets of holes are indicated on the drawings of Fig. 128.

Order of firing.	Kind of holes.	Depth, ft.	Charge, lbs.	Kind of dynamite.	Remarks.
	Bench Holes.				
1st round.	7 grading.	3 to 5	50	40% Climax.	Angle of inclination to suit conditions.
2d "	5 bench.	9.5	45	40% "	Fired together in 70% of blasts; angle of inclination to suit conditions.
	Heading Holes.				
2d "	6 trimming.	3 to 9	42	40% "	
3d "	8 center cut	9	56	60% "	In 50% of blasts, holes charged 2d time, requiring 40 lbs. additional; occasionally charged a third time with 24 lbs. additional.
4th "	8 side.	8	48	40% "	In 25% of blasts 10 side holes are used, requiring 12 lbs. additional.
5th "	6 dry.	8	36	40% "	In many instances the extra side holes and two dry holes farthest from center are fired before the 4 center dry holes.

Note.—Size of all holes tapers from 3 to 2¼ ins.

The removal of the spoil was accomplished by means of dump cars running on 36-in. gage service tracks. At 157th St. an incline was graded which branched north and south into the 158th St. and 155th St. portals, respectively. The cars were hauled by mules to the portals and were then taken up the incline and to the 162d St. dump by small locomotives. At 168th and 181st streets the cars were taken to the bottoms of the shafts by mules, then hoisted to the surface in elevator cages, and then taken to the dump. The bench was kept close to the heading at all times, so that the heading spoil had only a short distance to be carried.

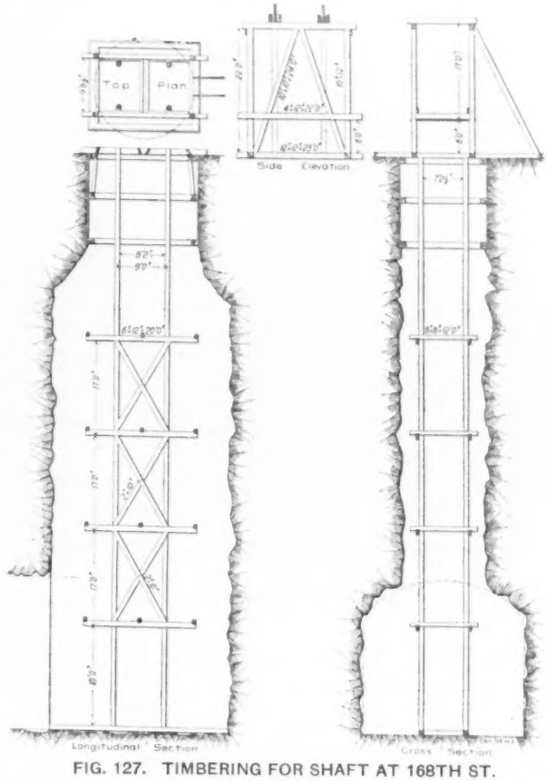

FIG. 127. TIMBERING FOR SHAFT AT 168TH ST.

At 168th and 181st streets the normal tunnel section had to be enlarged to accommodate the underground stations at those points. The plan adopted by the contractors was to carry the normal section through the stations so as to hasten work and to widen out the excavation for the station as the occasion permitted. The station chambers were each about 300 ft. long, and the clear excavation called for was 53 ft. wide and 28½ ft. high. These chambers were finally lined with concrete arches on vertical sidewalls. The arches were three-centered, the radii being 34 ft. and 13.44 ft., respectively. These station chambers were excavated without timbering.

On Sections 13 and 14 there is approximately 500 ft. of soft ground tunnel as follows: 155th St. tunnel, 100 ft.; 158th St. tunnel (at 160th St.), 75 ft.; Fort George tunnel, 325 ft. In the cases above mentioned, it was decided to tunnel even though the top of the rock was from 10 ft. to 12 ft. below the roof of the tunnel. This method was adopted on account of the great depth of cut and the elaborate system of timbering required for bracing and shoring a trench of such depth.

The general method of timbering in the various stages is shown in the longitudinal section and cross-sections of Fig. 129. The first stage of this work consisted in putting up a bulkhead across the cut where it was intended to begin tunneling, and then erecting bents consisting of two 12-in. × 12-in. × 6-ft. batter posts 6 ft. apart, founded on blocks, and a 12-in. × 12-in. × 8-ft. cap (Section A-B),so that the bottom of the cap should be 4 ft. above the ordered line of excavation in order to leave room for the crown bar and segmental timbering which would come later. Above this cap poling boards 3 × 6 ins. × 4 ft. long were driven in, slightly inclined upward (longitudinal section), and earth excavated beneath them, giving them temporary support of posts, and shoring the sides until another bent could be put in place 3 ft. ahead. This method was continued for at least 20 ft., spacing bents 3 ft. apart. When the drift had progressed far enough to allow a 16-ft. crown bar to be put in, the work of deepening and widening out was begun (Section C-D).

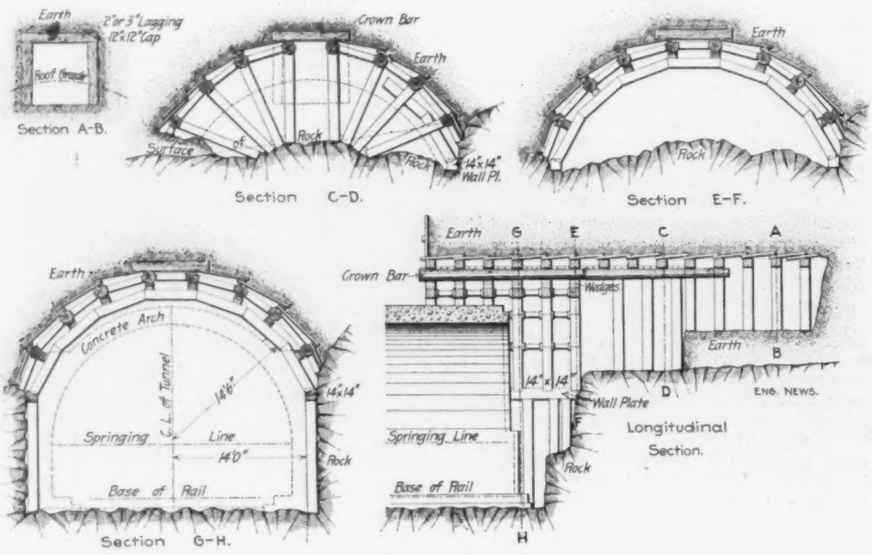

FIG. 129. SKETCHES SHOWING METHOD OF TIMBERING AND ADVANCING TUNNEL IN SOFT ROCK.

The third stage of the work or segmental timbering was then begun by placing in this trench either 14 × 14-in. or 12 × 12-in. wall plates, about 16 ft. long, and from these plates, cut skewback, the segmental timber sets were erected, as is shown in C-D and E-F. When each set was keyed in, the support of the crown bar was transferred to it by blocks and the upright and radial supports removed. The seven timbers that go to make up a timber set were each 12 × 12 ins. × 5 ft. 2 ins. on the intrados, and 5 ft. 6 ins. on the extrados. The sets were spaced from 3 ft. to 5 ft. apart. The work in all three stages could be and often was carried on simultaneously. When the heading had progressed sufficiently, the work of taking out the bench, which was generally poor rock, was begun, and plumb posts reaching below subgrade were put in under the wall plate and directly under each timber set (Section G-H).

The thickness of the concrete arch in soft ground varies from 21 ins. to 27 ins., and the haunch is carried solid to the poling boards at least 8 ft. above the springing line. The remaining space above the arch was carefully packed, leaving the timber in place. It will be noticed that in Section G-H a clearance of 12 ins. above the concrete is shown, which is designed to give room for settlement of the timbers, but this clearance is materially diminished by the increased thickness of the arch. In some cases where the exigencies of the case required, the haunch has been carried solid to poling board lagging to a height of 9.5 ft. above springing line. At Fort George a section of arch was built having a solid haunch 11 ft. above springing line, in which twisted steel rods were used as additional reinforcement on account of the unbalanced pressure due to slope of surface.

Figs. 130 and 131 are views inside this tunnel, showing the appearance of the timbering described above.

CONCRETE LINING.—The tunnel work was lined throughout with concrete. This lining had vertical sidewalls 25 ft. apart, carrying a circular roof arch of 25 ft. span. The lining was placed by means of traveling centers and sidewall molds similar in general design and construction to those used on Sections IV. and VII., previously described. Instead of mounting these traveling platforms on wheels running on track rails, however, the contractors used pieces of cast-iron pipe as rollers. Before any concrete was deposited these centers were wedged up off the rollers. These rolling platform side molds and centers proved entirely satisfactory. Fig. 132 shows the traveling centers and the completed roof arch behind them.

There was practically no concrete made by hand on either section. For the open cut portion of the work a central mixer was located at 147th St. This was a 3 cu. yd. cubical box mixer mounted low in the cut with a platform above it for handling materials, sand and stone being loaded from bins by chutes into cars and cars dumped directly into mixer. The concrete was hoisted out in buckets, loaded in cars and delivered by locomotive at any point along the line.

At 155th St. a rotary mixer was used and the materials were loaded in cars and pulled up an incline by air, dumping directly into the mixer. The concrete came from the mixer by chute into

FIG. 130. VIEW SHOWING ADVANCE DRIFT IN SOFT ROCK TUNNEL.

FIG. 131. VIEW SHOWING TIMBERING FOR WIDENING ADVANCE DRIFT IN SOFT ROCK TUNNEL.

The drift was excavated to a depth of about 10 ft. and 12 × 12-in. uprights about 9 ft. long were put in place on a foundation of blocks, or rock, as is shown in Section C-D, and 16-ft. crown bars were put in place under the caps. Then the original uprights were removed, the crown bars cross braced (not shown in C-D), and the work of

cars on the floor of the tunnel and these were delivered at the working point, as will be described later.

At the 168th St. and the 181st St. shafts there was located a cubical box mixer holding 64 cu. ft. This was mounted just high enough above the tunnel floor to allow the

concrete to run into the delivery car. A platform was built above it for the purpose of handling materials. Stone and sand were delivered to bins built in the roof of the drift and side of shaft, by chutes, and from the bins into cars on the platform. The cars discharged into the mixer through a bottom door. Concrete received from this mixer in cars was delivered to the foot of the

FIG. 132. VIEW SHOWING TRAVELING CENTERS FOR CONSTRUCTING LINING OF TUNNEL.

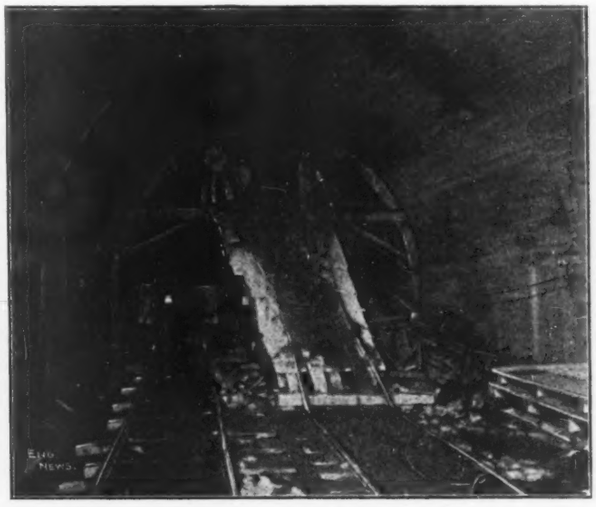

FIG. 133. VIEW SHOWING INCLINE FOR TAKING CONCRETE CARS TO PLATFORM ON TRAVELING CENTER.

incline to the arch centers by mules. These cars were hoisted to the platform on the arch centers (Fig. 133) by compressed air and dumped; from this platform it was shoveled in place over the arch forms, the arch being turned up to 3 ft. each side of center of "key" and 6-ft. "key" put in place in the usual way.

At Fort George a gravity mixer was used and the sand and cement delivered by trucks, but the stone was run from crusher to platform by cars.

Broken stone was supplied to the mixers at 147th and 155th Sts. by cars from a crusher located on the dump at 162d St. and Lafayette Boulevard. The 168th St. mixer was supplied by a crusher located in the tunnel at the 181st St. shaft, at first delivered by trucks, but afterwards by cars through tunnel direct to mixer platform.

POWER PLANT.—Compressed air for tunneling purposes was supplied by a central plant located between 162d and 163d streets, on the North River. This plant had four 125-HP. boilers and one 170-HP. boiler, which operated a plant of three Rand compressors, 24 × 30 × 30 ins. From these compressors pipe lines extended to the two ends of the work.

ENGINEERS.—The work on Sections XIII. and XIV. was carried out under the direction of Mr. Beverly R. Value, M. Am. Soc. C. E., as Division Engineer, until his resignation, and afterwards under the direction of Mr. C. V. V. Powers, as Division Engineer, and Mr. Stephen U. Hopkins, as Assistant Engineer. Mr. R. C. Hunt was General Manager for the contractors.

BURNING ILLINOIS COAL WITHOUT SMOKE.*

By L. P. Breckenridge, M. Am. Soc. M. E.†

No difficulty is experienced in burning Pennsylvania anthracite coal without smoke. This is because of its freedom from what is known as volatile combustible. As we go west we find the semi-bituminous coals of western Pennsylvania and Ohio, which contain a larger percentage of volatile combustible. These coals need care in firing. It is when we reach the coal fields of Indiana, Illinois, and the States farther west that we experience still greater difficulties in burning the bituminous coals, which frequently contain as high as 40% volatile combustible, together with often 3 to 5% of sulphur. Considering all the practical difficulties involved, a decided advance has been made towards the solution of the problem which we meet here to discuss.

There are certain well-established laws of combustion, and certain methods of constructing and operating furnaces, which, if we apply correctly, we may expect to burn Illinois coal without smoke. There are, however, many practical difficulties experienced in bringing about all of the necessary conditions at the same time, in perhaps six different furnaces all connected to the same stack. The conditions necessary to secure smokeless combustion of bituminous coal are as follows:

A. The gases must be distilled from the coal *slowly*.

B. The distilled gases must be *intimately* mixed with *hot air*.

C. The gases must not be allowed to come in contact with cool surfaces before complete combustion has taken place. The various appliances and methods used for preventing smoke emphasize one or a combination of these principles. In this discussion of the smoke problem let us consider the two following important phases of the question:

1. What lines should be followed in the construction of new boiler plants?; 2, What can we do with existing plants?

There can be no question as to the possibility of constructing a boiler plant which will burn Illinois coal and which can be operated a very large part of the time without objectionable smoke. The essential features of such a plant would be: 1, Sufficient boiler capacity; 2, A good draft; 3, Uniform size of coal; 4, Some good type of automatic stoker; 5, Intelligent direction in the boiler room.

1. Sufficient capacity must be provided so that it will be possible to "lay off" one unit for repairs, as it is very essential for satisfactory work that the fire brick arches be maintained in good repair.

2. A good draft may be secured by a stack or by the induced fan system. The draft directly above the fire should be ⅝-in. This will be secured by a stack draft of ⅜-in. to 1-in., with all of the standard types of water-tube boilers and with properly proportioned fire-tube boilers. Many failures of good furnaces have been due to a poor draft.

3. Not enough attention has been paid to the uniformity in the size of coal. This is a matter of much importance in connection with the smokeless operation of automatic stokers. Large plants should be provided with crushing machinery so that at times, when the sizes desired cannot be obtained, the crushing may be done at the boiler house. Most stokers work with greater regularity with the smaller sizes of coal, such as nut, pea, or slack.

4. There are now on the market at least four distinct types of automatic stokers: A, the inclined grate; B, the chain grate; C, the under-feed; and D, the rotary grate. Any of these types will operate without smoke when sufficient draft is provided and when they are properly set under any of the standard boilers. There are, of course, numerous cases where all forms of furnaces have proved a failure, and it is the knowledge of these failures that keeps the owner in a state of doubt as to what should be done to meet the conditions which arise in his particular case. No better plan can be followed than to submit the case to an expert mechanical engineer, who should examine the conditions and prescribe the proper treatment.

5. Intelligent direction in the boiler room is the most important feature of the above-named essentials of a smokeless plant. It will require intelligent direction to operate even the best plant without smoke.

It frequently happens that with a given draft some coals work better than others. It takes a reasonable time for a fireman to learn how best to handle a given grade of coal. In many buildings the location of the boiler room is such that the fireman cannot see the top of his stack, and it is very difficult for him to become familiar with the effect of the various methods of firing which he may wish to try. The possibilities for economy are nowhere greater to-day than in the boiler room.

The following is a brief outline of the essential features of the boiler plant at the University of Illinois. It consists of the following units:

1. One hand-fired furnace under a 150-HP. special Babcock & Wilcox boiler built for a working pressure of 275 lbs.

2. One chain-grate stoker under a standard 150-HP. Babcock & Wilcox boiler.

3. One Brightman stoker under a 110-HP. horizontal tubular boiler.

4. One Murphy smokeless furnace under a 250-HP. National boiler.

5. Two Roney automatic stokers under two 220-HP. Babcock & Wilcox boilers.

The draft for the plant is furnished by a brick chimney, 6 ft. inside diameter and 150 ft. in height. The amount of draft varies with the number of furnaces in operation. It is from ¾-in. to 1¼-ins. at the base of the stack, and the flue areas to each boiler furnace are ample.

The coal burned during the past year has been furnished by the Springfield Coal Mining Co. and is mined in Sangamon Co., Ill. The size is that known as "pea" and it has been comparatively free from "dirt." It has cost the University $1.37 a ton at our boiler house. A recent chemical analysis shows the following composition:

Water	7.9%
Volatile combustible	35.3%
Fixed carbon	39.7%
Ash	17.1%
Total	100.0%
B. T. U. by Parr calorimeter	10,268

Sulphur—5.2%.

Analyses made from time to time show considerable variation in composition, but it will be noticed that like all Illinois coals it is high in volatile combustible and low in fixed carbon. It is on account of the large volatile content that difficulty arises in burning this coal without smoke. Numerous attempts have been made to "hand fire" this coal without smoke in furnace No. 1, but without much success. Experiments have also been made in this furnace with "steam jets" and special bridge wall air supplies, but in no case have we been able to equal the performance in preventing smoke of any of the mechanical stokers here referred to.

Whenever it has been necessary to operate *all* of the boilers in this plant, the smoke from the hand-fired furnace has been sufficient to produce black smoke fully one-third of the time. A stoker will undoubtedly replace this furnace during the coming summer.

Under favorable conditions any one or all of the stokers in this plant can be operated without smoke. During the past winter the writer believes that this plant was operated for fully 85% of the time without objectionable smoke, whenever the hand-fired furnace was not in use. There are, however, times when the prevention of smoke seems impossible. This frequently occurs at a very inopportune time. Some of the causes which operate to produce smoke are: A, sudden change of load due to the shutting off of steam from one or more buildings; B, cleaning fires; C, deterioration of the fire brick arches; D, faulty feeding of fuel; E, carelessness on part of the attendant.

*From a paper read before the Commercial Club of Chicago on its visit to the University of Illinois at Champaign, Ill., May 19.

†Professor of Mechanical Engineering, University of Illinois, Champaign, Ill.

We have experimented at the University with a large number of Illinois coals. We have found some variation in treatment necessary with different coals. We have installed here various standard types of furnaces and boilers, having in view their educational as well as their commercial use. With the added facilities which will be possible in the immediate future, we shall endeavor to continue investigations here which shall be of interest and value to the great industrial interests of this great state.

WHAT CAN WE DO WITH EXISTING PLANTS?—This is a problem which is more difficult of solution. It is perhaps the problem which interests you most. There are many plants in which Illinois coals cannot be burned without smoke. At some plants the conditions are such that often only a careful examination by a competent expert will reveal what steps should be taken.

One serious defect, namely, *lack of space*, is responsible for much of the smoke production in existing plants. The desire to rent or use every possible square foot of space in the basement has resulted in reduced rental values for rooms higher up, on account of the smoke issuing from an adjoining stack. If the space available prohibits the use of an approved stoker, there are several types of hand-fired furnaces that can, with a good draft and reasonable care in firing, be depended upon to give good results. The types most familiar to the writer are as follows: The "Down Draft" furnace; the "Dutch Oven" furnace the "Wing Wall" furnace; the "Twin Fire" furnace.

In these furnaces the coal is shoveled in by the fireman and no mechanical devices are used. There are doubtless other types that will give fair results.

The use of steam jets properly arranged will serve to check a very large percentage of the smoke from the common furnace. This device is doubtless the cheapest of all smoke-preventing appliances. Its use will involve the consumption of from 6 to 10% additional coal because of the steam used by the jets; but for small plants this method may prove worth consideration on account of its simplicity and low first cost. The noise made by the jets is objectionable in some places.

The method of firing ordinary furnaces has considerable influence on the amount of smoke produced. Unfortunately, the most approved methods of firing require somewhat harder work on the part of the fireman. For this reason mechanically operated furnace appliances are, in the long run, more successful. The skilful fireman is acquainted with the most approved methods of reducing smoke. These are usually known as A, the "one-shovel" system; B, "one-side firing," and C, the "coking system." The latter seems to be the most successful as well as the most scientific.

The use of powdered fuel presents an attractive field for experimentation, but a sufficient amount of reliable information has not yet become available to warrant its presentation at this time.

In closing let me make a few general statements which the writer believes will meet the approval of those mechanical engineers who have taken pains to inform themselves concerning the details of the smoke problem.

1. It is feasible to design and construct new boiler plants in which Illinois coal may be burned without objectionable smoke.
2. There will be times at which smoke will be produced even in the most carefully-operated plants. This should not exceed 10% of the time that the plant is in operation.
3. Mechanically operated furnaces are most satisfactory for large plants (above 500 HP.), both on account of their freedom from smoke and their greater economy of fuel and attendance.
4. A good draft is a prime requisite of smokeless combustion.
5. There are special types of hand-fired furnaces which can be depended upon for smokeless combustion.
6. The application of steam jets will check smoke and should be used if no better way can be arranged. The cost of coal required to operate the steam jets for a 100-HP. boiler for ten hours would be $1, with coal at $4 a ton.
7. The coal should be burned on as small a grate area as is feasible; this means a thicker and hotter fire, better economy and less smoke.

The suppression of smoke in a large city is a problem of much difficulty. Only by organized and co-operative effort can it be accomplished. It can not longer be said that ways and means are not available. The present difficulties are not due to a lack of appliances as much as to a lack of knowledge as to what should be used in a special case.

TESTS OF THE EFFICIENCY OF HOISTING TACKLE.

By S. L. Wonson.*

The Erecting Department of the American Bridge Co., of New York, recently carried out an extended series of tests upon the efficiency of hoisting tackle, using its standard types of blocks, with various combinations of manila and wire rope.

The tests were made upon the eyebar testing machine of 600 tons capacity at the Pencoyd plant of the American Bridge Co., and were intended to reproduce as nearly as possible actual field conditions. One block was attached to the fixed head and one to the movable head of the machine, the latter having a horizontal motion, under constant pressure, of about 6 ft. The line was led as shown in the accompanying sketch, Fig. 1, from the movable block back to a snatch block at the fixed end of the machine, thence with a 180° turn to a second snatch block, thence with a 90° turn to a vertically moving hydraulic crane, which furnished the lead line pull. The load registered on the testing machine was thus carried on as many parts of line as ran to the movable block, this number being one in excess of that leading to the fixed block.

The load on the machine and the pull exerted by the crane were taken from their respective mercury pressure gages, upon which a large number of simultaneous readings were made for each individual test. Separate readings were of course taken to determine the friction of testing machine and crane. Each combination of tackle was tested in lifting, i. e., with the movable block approaching the fixed block as in lifting a load, and in a becket pull, i. e., with the movable block receding from the fixed block as in lowering a load.

The results of these tests are shown in Table I. The tested efficiencies there given are derived as follows: If W be the load on the machine, n the number of parts of line carrying the load and P the pull of the crane, the tested efficiency for straight lifts is $\frac{W}{n\,P}$; for the becket pulls, in which the machine is pulling against the crane, an analogous value for efficiency is $\frac{n'\,P'}{W'}$, where W' is the pull of the machine, n' the number of parts of line, and P' the resistance of the crane. It should be noted that the results of the individual tests as given in the column of tested efficiencies are each derived from a large number (in most cases 40 to 50) of gage readings.

Fig. 1. Arrangement of Blocks and Lines for Efficiency Tests.

Under field conditions a lead line is frequently snatched a number of times before reaching the engine. It was desired therefore to obtain results of the tests free from the influence of the two snatch blocks used, and involving only the parts of line holding the load, of which the first should be considered the lead line, as shown in the sketch Fig. 2.

Fig. 2. Arrangement Without Snatch Blocks; Efficiencies Calculated.

For this purpose the efficiencies of the combinations tested were worked out according to the method given by Weisbach in "The Mechanics of

TABLE I.—RESULTS OF TESTS OF THE EFFICIENCY OF HOISTING TACKLE WITH TWO SNATCH BLOCKS

Kind of rope.	Parts of line.	Tested efficiency, %. Lifting.	Mean.	Becket pull.	Mean.	Efficiency from formula. Lifting.	Becket pull.
1¼-in. Manila line.... C = 0.46	4	60, 60, 56, 57, 55, 53	57	37, 42, 50, 56, 57	48	60	58
	6	52, 51, 53, 52, 52	52	56, 50	53	53	50
	7	44, 48, 52, 51	49	41, 46	44	50	45
1½-in. Manila line.... C = 0.40	4	52, 48	50	47, 50	49	56	55
	7	46, 46	46	42, 43, 43	43	47	42
	9	48, 48, 56, 52, 52, 43, 43, 43, 41	47	40, 37, 38	38	42	36
1¾-in. Manila line.... C = 0.38	5	45, 47, 44	45	48, 49, 49	49	47	45
	7	39, 42, 41	41	43, 33, 42	40	42	37
	9	37, 41, 39	39	34, 33, 36	34	37	31
2-in. Manila line..... C = 0.34	7	39, 41, 44	41	32, 38, 37	36	40	36
	9	36, 38, 39	37	37, 37, 39	38	35	30
¾-in. wire rope ..... C = 1.8	3	47, 48, 46	47	42, 47, 40, 35	41	..	..
	5	49, 48, 49	49	42, 41, 42	41	..	..
	7	49, 50, 49	49	46, 45, 41	44	55	56
	9	53, 58, 55, 49	54	41, 44, 43	43	50	49
	13	43, 44, 48, 46	45	53, 51, 51, 51	52	42	37

*Assistant Engineer Erecting Department, American Bridge Co., of New York.

TABLE II.—Capacity and Efficiency of Hoisting Tackle without Snatch Blocks.

Kind of rope.	Parts of line.	Lift per unit pull in lead line.	Efficiency, %.
1¼-in. Manila line	2	1.92	96
	3	2.68	89
	4	3.37	84
	5	3.95	79
	6	4.48	75
	7	4.92	70
1½-in. Manila line	2	1.91	96
	3	2.67	89
	4	3.36	84
	5	3.93	79
	6	4.45	74
	7	4.89	70
	8	5.28	66
	9	5.61	62
1¾-in. Manila line	3	2.64	88
	4	3.30	83
	5	3.84	77
	6	4.33	72
	7	4.72	67
	8	5.08	64
	9	5.37	60
2-in. Manila line	5	3.87	77
	6	4.37	73
	7	4.78	68
	8	5.14	64
	9	5.45	61
¾-in. wire rope	3	2.73	91
	4	3.47	87
	5	4.11	82
	6	4.70	78
	7	5.20	74
	8	5.68	71
	9	6.08	68
	10	6.46	65
	11	6.78	62
	12	7.08	59
	13	7.34	56

Hoisting Machinery."* The formula there used for the efficiency of a fixed pulley is,

$$\frac{1}{K} = \frac{1}{1 + C\frac{S^2}{r} + 2\phi\frac{P}{r}\sin\alpha}$$

where

S = diameter of rope;
r = effective radius equals distance center of pulley to center of rope;
P = radius of sheave pin;
2α = arc of contact of rope on sheave;
ϕ = coefficient of journal friction = 0.08;
C = empirical constant.

The efficiency of the movable pulley is: for forward motion or lifting $\frac{1+K}{2K}$; for reverse motion or becket pull $\frac{2}{1+K}$.

It was found that a constant value of C did not give computed efficiencies agreeing sufficiently well with those of the tests. Different values of C were accordingly selected for the different sizes of rope; they are given in Table I. together with the efficiencies computed from the formula.

The constant C for ¾-in. wire rope was derived from the tests on 7, 9, and 13 parts of line, as the friction of the testing machines in the tests on 3 and 5 parts of line was so large in proportion to the load lifted as to render the results of the two tests of doubtful value.

Table III. contains the essential dimensions of the blocks tested.

Having determined a suitable value of C for each size of line it only remained to compute the efficiencies of the several combinations, omitting the snatch blocks. The results are shown in Table II., together with the lift of each combination per unit pull in lead line, the lead being, as explained above, the first part of line holding the load.

The tests were carried out under the general supervision of Mr. S. P. Mitchell, Chief Engineer of the American Bridge Co., of New York, and were personally directed by Mr. J. L. de Vou, Assistant to Chief Engineer.

TABLE III.—Dimensions of Blocks used in Tests.

	Center of sheave pin to tread of sheave, ins.	Diam. of sheave pin, ins.
12-in. blocks for 1¼-in. Manila line	3½	⅞
14-in. " " 1½-in. " "	3¹³/₁₆	1
16-in. " " 1¾-in. " "	4½	1⅛
20-in. " " 2-in. " "	5½	1⅜
Snatch blocks for Manila line	3⅝	1
Wire rope blocks	7	2½

Note.—All blocks were metaline-bushed.

*Translated from the second German edition by Karl P. Dahlstrom, M. E.

SOME TESTS OF BOILER AND FURNACE EFFICIENCIES.*

By A. Bement.†

It is the object of this paper to discuss some features of the performance of modern standard boilers and furnaces.

For this purpose two types of boilers, two furnaces and one stoker have been selected; one of the boilers, however, owing to changes made in it, may be considered as a third type.‡

One of the boilers is 12 tubes high and 16 wide, provided with a superheater and rated at 400 HP. It is equipped with a chain-grate stoker of 65.5 sq. ft.; the gases from the fire discharge among the tubes of the heating surface located immediately above, thence down across the tubes of the second pass and finally rise on the way to the flue across the tubes of a third pass. This boiler is referred to as boiler A. The other boilers are of two sizes. That designated as No. 1 is 15 tubes high and 19 wide. No. 2 is 17 tubes high and 19 wide. With each the gases travel from the bottom of the back and diagonally across the tubes to the upper front end, thence back between the drums to the flue. No. 3 adjoins No. 2 in battery, and is identical with it except that the path of the gases from the back end is forward among the lower tubes of the second to the seventh rows; thence to the front end of the boiler, then back among the next five rows and finally forward among the upper five rows, where they pass between the drums to the flue. In this arrangement the gases traverse the length of the tubes three times in place of the one diagonal travel of boilers Nos. 1 and 2. The furnaces under these boilers are identical, and each is fitted with a chain-grate stoker of 72.2 sq. ft. The tubes in the lower row of the boiler are entirely encircled with a fire-brick tile from the front to a point back of the bridge wall; for the remainder of the distance to within 4 ft. of the back end the usual tile furnished by the maker of the boilers is used.

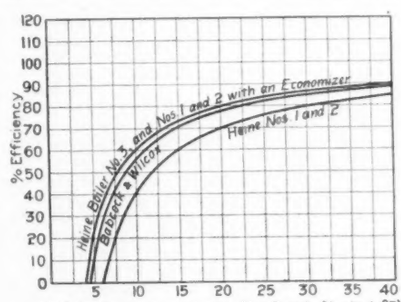
% Efficiency
Heine Boiler No. 3, and Nos. 1 and 2 with an Economizer
Babcock & Wilcox
Heine Nos. 1 and 2
Initial Temperature above Air Supply (Hundreds °F.)

Fig. 1. Efficiency Curves of Heine Boilers Nos. 1, 2 and 3, and Babcock & Wilcox Boilers.

TABLE I.

	Boilers— Boiler A.	No. 1.	No. 2.	No. 3.
Sq. ft. of water-heating surface	4,000	4,340	4,800	4,800
Sq. ft. of steam-heating surface	383	...	...	...
HP., standard rating	400	434	480	480
" maker's rating	400	570	645	645
" developed	442.8	431.5	564.3	580.4
" developed above standard rating.	10.7%	...	17.6%	20.9%
" developed below standard rating.	...	.06%	..	...
" developed below maker's rating.	...	32.1%	14.3%	11.2%
Length of travel of gases in contact with tube-heating surf., ft.	21	13	13.3	36
Temp. of escaping gases, F. degrees	480.2	650.5	657	469
Temp. of escaping gases above saturated steam	127.8	273.1	278	92
Temp. of escaping gases above air supply	407.9	580.2	582	394
Temp. of saturated steam	352.4	377.4	379	377
Temp. of superheated steam	455.8	...	...	...
CO_2	9.22	7.93	10.7	10.3

Table I. contains the essential data concerning the boiler trials. Boilers A and No. 1 are practically of the same size, although the HP. of the latter is rated by its maker 31.3% above the former. The HP. developed above that of No. 1 by boiler A is 10.70% and its CO_2 is higher; but owing to unburned volatile combustible equal to 8.79% of the total combustible, the condition of combustion is less favorable for this boiler than appears from the CO_2 measurement. The conditions for these two boilers may, therefore, be considered the same, except that with A, the saturated steam temperature was 25° lower; for this reason its final temperature has been raised that amount, so that the comparison shall be on the same basis.

In the case of boilers Nos. 2 and 3 the combustion was complete. With No. 2 the air supply and HP. were slightly less, giving it a small advantage over No. 3.

Conditions of operation being the same, the difference of cooling effect is shown by the difference in final temperature measured above that of the air supply; this referred to the initial temperature, also above that of the air supply, determines the efficiency of the boiler.

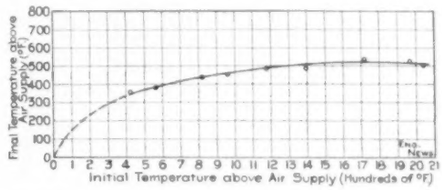

Fig. 2. Relation of Final to Initial Temperature; Heine Boiler No. 2.

Fig. 1 illustrates the relative efficiency of the four boilers that are being considered. The initial temperature is shown through a range that covers all attainable conditions. From an inspection of the curves, it appears that the efficiencies of boilers Nos. 1 and 2 fall upon the same line, and that of A, which varied from the furnace temperature, is from about 4% at 4,000° to 20% at 720° above the efficiency of Nos. 1 and 2, while No. 3 is more efficient than that of A.

The efficiency curves are based on the final temperature being constant through the full range of the initial. To what extent this is true is shown by Fig. 2, which illustrates the relation between initial and final temperature, the curve being plotted from simultaneous measurements. It appears that within usual working ranges the final temperature remains quite constant. The value of the relative efficiencies from the standpoint of fuel saving is quite important. It is shown in Fig. 3; the efficiency of boilers Nos. 1 and 2 being taken as the standard. The value of an efficient boiler when served by an inefficient furnace, is forcibly illustrated.

The boiler and furnace of type A, having no special features, are not shown, but Fig. 4 is a vertical longitudinal section illustrating boilers Nos. 1, 2 and 3. The heavy arrow shows the path of the heated gases through Nos. 1 and 2. The travel in No. 3 is shown by the dotted arrows. The two baffles added in this boiler are indicated by the horizontal dotted lines; the lower of these was located so that between its ends and the back-water leg there is a space of 4 ins. left open for the full width of the boiler, to allow dust to drop down to the chamber below. Owing to this opening, the gas travel is split into two parts, a minor portion taking the more direct and shorter route by way of this opening, as shown by one of the dotted arrows, so, in fact, the effect on the hot gases of the three passes is not entirely secured. Fig. 5 illustrates a section of the tiles which encircle the lower row of tubes and provide a tile roof to the furnace extending beyond the bridge-wall. The application of these tiles was devised by Mr. W. L. Abbott,* for reasons that will be discussed later. Fig. 6 shows the tiles which close the spaces between the lower row of tubes back of the encircling tile. They are those regularly supplied by the maker of the boiler, and leave the lower half of the tube exposed to the passing hot gas and are usually known as the T-tile.

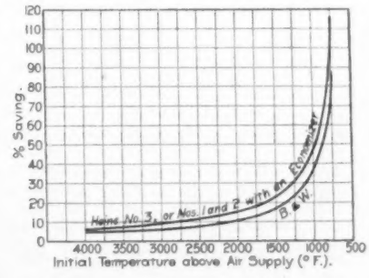

Fig. 3. Saving Made Over Heine Boilers Nos. 1 and 2 by Babcock & Wilcox Boiler and Heine No. 3.

Inasmuch as there is a great difference in the cooling effect between the boilers compared, it will be interesting to study the reason therefor, and also to examine the drop in temperature of the gases on the way through the heating surface. Regarding this latter phase of the matter, Table II. gives in detail the performance illustrated in

*Extract of a paper read at the annual convention of the National Electric Light Association at Chicago, May 26, 27, 28, 1903.

†Expert in Furnace Practice and Gas Analysis; 218 La Salle St., Chicago.

‡Note.—Boiler A is of the Babcock & Wilcox type at the Harrison St. station of the Chicago Edison Co., Chicago. Boilers 1, 2 and 3, are of the Heine type: No. 1 being at the plant of the Commonwealth Electric Co., Chicago, and Nos. 2 and 3 at the Harrison St. station of the Chicago Edison Co. All the four boilers are equipped with Babcock & Wilcox chain grates.—Ed.

*Chief Operating Engineer, Chicago Edison Co., 139 Adams St., Chicago.

Fig. 7, which is a curve of temperature drop through the surface of boiler A plotted from measurements taken during the trial.

From this it appears that the same length of travel in the last pass gave only 6.7% of the cooling effect of the first pass, illustrating the importance of the gases being in contact with the heating surface for as long a period as practicable if large cooling effect be secured.

TABLE II.

Temperature,	initial	2,012°	F.	
"	at end of first pass...	908°	"	
"	at top of second pass.	680°	"	
"	bottom of third pass.	555°	"	
"	at final	480.2°	"	
Drop in temp.,	first pass	1,107°	"	72.064%
" "	drums	158°	"	10.29%
" "	superheater	70°	"	4.59%
" "	second pass	125°	"	8.16%
" "	third pass	75°	"	4.890%
	Total	1,532°	"	100.000%
HP. developed	in first pass	321		
" "	in drums	44		
" "	in superheater	20		
" "	in second pass	35		
" "	in third pass	22		
	Total	442		

As the volume of the gases decreases rapidly with drop in temperature, it is probable that boiler A would be improved by passing the gases across it four times in passages of properly proportioned size, not adding to the amount of heating surface, but bringing more of it into active use; because with this boiler, as with Nos. 1 and 2, the tendency is for the gases to flow in a narrow path diagonally across the tube surface of the pass.

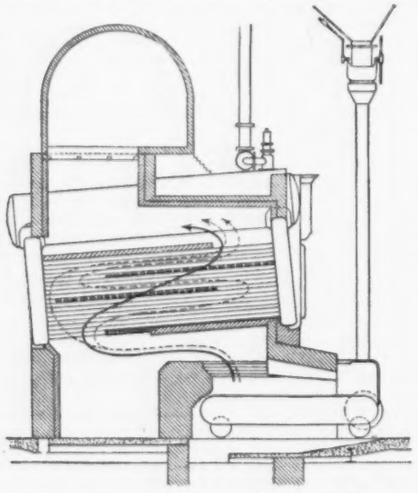

Fig. 4. Longitudinal Section of Heine Boilers, Nos. 1, 2 and 3.

It is apparent that the greater efficiency of boiler A as compared with No. 1 is not owing to difference in amount of heating surface, but to greater length of travel of the gases in contact with the same amount of surface, or, in other words, greater length of time for the transfer of heat. This is still better illustrated by boilers Nos. 2 and 3.

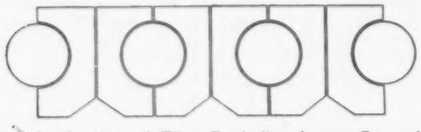

Fig. 5. Section of Tiles Encircling Lower Row of Tubes of Heine Boiler.

The efficiency of the A type as compared with that of Nos. 1 and 2 is based on this particular type, which is a high "double-deck" apparatus, and it does not follow that a lower type would show such superiority. This may be illustrated by assuming that boilers A and No. 1 be each reduced one-half in height, when the effect would be that the length of the travel of the gases with A would be reduced 50%, while with No. 1 the reduction would amount to less than 10%; so, as the height is less, the efficiency of A drops off very much faster, and while the gain in the high No. 2 over the low No. 1 type is small, with that of A it is very large.

Fig. 6. Tiles Enclosing Spaces Between Lower Row of Tubes, Back of the Encircling Tiles.

The initial temperature, or, in other words, the condition of combustion, has more effect on the efficiency of the steam-generating apparatus than has the cooling effect of the boiler. This is shown by the efficiency curves Fig. 1, and if choice lay between the two, that of high initial temperature would be chosen; but high initial temperature is always dependent on skilful manipulation of the fire, and its attainment is difficult and more or less uncertain, while the superior boiler efficiency has a fixed value not dependent on the skill of the operator, and this value increases as the initial temperature decreases. There might be some question as to whether the full value of a good furnace would always be realized, but there could be no failure to realize the value of an efficient boiler.

The most remarkable feature of this matter of boiler efficiency is that the simple addition of inexpensive baffles, with no labor cost for operation and requiring no additional room in the plant, give results equal to an economizer requiring a large investment, considerable expense for maintenance, and a large amount of space for its installation.

FURNACE EFFICIENCY.

The foregoing refers to the boilers only, and it is now in order to examine the furnace performance. The comparative test between A and No. 1 gave the following relation between the two apparatus:

	A.	No. 1.
1. Efficiency of combined boiler and furnace.	57.83	59.12
2. Efficiency of boiler	77.69	70.12
3. Superior efficiency of boiler	7.57	....
4. Superior efficiency of furnace	...	8.86

Item 1 includes all losses except that of combustible in the refuse, all other losses except hot gases and combustion being the same for each apparatus.

Item 2 is the measure of the cooling effect produced by each boiler.

Item 3 is the difference in the cooling effect produced by the two boilers.

The superiority of the furnace under boiler No. 1, item 4, is owing to better combustion, there being a loss of 8.86% with the furnace of the A boiler, due to escaping hydrocarbons and incomplete combustion, the air supply being considered the same in each case. The reason for the difference in combustion with these two furnaces will be understood when each is examined in detail. The furnace under the numbered boilers will hereafter be referred to as the tile-roof furnace, and the other as the A furnace; the former is shown in elevation by Fig. 4; the roof is made with tiles shown by Figs. 5 and 6. The distance from the coal gate at the front of the furnace to the end of this tile roof is 16 ft., a distance through which the gases must travel before coming in contact with the boiler surface except in the lower half of the bottom row of tubes, which for a distance of about 4 ft. back of the bridge-wall are exposed as shown by Fig. 6, there being a distance of travel of 12 ft., with no cooling effect, except that of radiation from the exterior furnace walls and through the tile roof. During the interval of time that the gases are moving through this distance of 16 ft. their mixture is proceeding, so that before they have reached a point among the tubes where the temperature has dropped to a point below which union will be effected, the mixture is completed; or, as more generally understood, complete combustion is effected.

With the A furnace the gases from the fire rise immediately and pass among the tubes of the boiler. There being not to exceed 3 ft. in distance for the gases to travel before the tubes of the boiler are reached, the temperature soon drops to a point at which chemical union does not take place; the result is an escape of unoxidized combustible in the form of hydrocarbons, carbon monoxide and free carbon.

The theory of the action of the tile-roof furnace may be given as follows: The coal entering at the front of the furance has its volatile matter rapidly distilled in the form of a hydrocarbon gas in excess of the air supply at the front of the fire, and flowing back meets a larger air supply from the back of the fire, where the fuel bed is thinner. With this it mixes, the excess of air from the back satisfying the deficiency at the front; and being thoroughly mixed in the chamber below the tile roof, it becomes, strictly speaking, a product of combustion at high temperature, which carries its heat from the furnace to the boiler. Assuming that the action of this furnace is as described, it would appear possible to obtain complete combustion with no air in excess; the indications are that this is possible.

With one of these furnaces carefully worked, and with the draft pressure at a certain determined intensity, it was possible to maintain an average as high as 17% CO_2, and for a few short intervals obtain as high as 19 according to the econometer connected to the furnace. There was no opportunity to test this condition with analysis, however, owing to the short duration of the intervals, but the econometer checked very closely with analysis at lower ranges. With the extremely small air supplies as given here, if the feed of coal was increased, it was accompanied by a raise in CO_2 to the apparent theoretical maximum, after which it fell, owing, presumably, to carbon being oxidized to carbon monoxide, but there appeared to be no tendency for carbon to be set free.

With the A type chain-grate stoker and boiler, or similar boilers and furnaces, the gas distilled at the front of the fire flows directly among the tubes, and results in loss by unburned hydrocarbons and free carbon, the latter making smoke, while the large excess of air from the thinner back end of the fire also flows directly among the tubes, but at a different point, and there is but poor mixture. With such furnace, the smoke and loss of hydrocarbons will drop off with increased excess of air, owing to a stronger draft; but the loss from this increased excess of air is greater than the combustion gain, therefore best efficiencies are to be obtained with the smoky condition.

THE CHAIN-GRATE STOKER.

This is the chain-grate stoker and is the nearest approach to an automatic machine; but in practice it is decidedly unsatisfactory so far as efficiency is concerned. The best performance secured with these stokers in the tile-roof furnace boilers is as follows:

	Example 1.	Example 2.
Efficiency	72.0	69.8
Lbs. of water evap. per hour per sq. ft. of heat surface	4.1	6.07
HP. per sq. ft. of grate	6.13	11.6

From these examples the efficiency has ranged down to 40% and capacity in proportion. The size of the coal used has an important effect on capacity—all other conditions being the same—and may affect the result as much as 20 to 80%. The greatest fault thus far recognized in chain-grate stokers is their leakage into the furnace at the back end of the grate. This and loss of combustible in the refuse are its major faults. With the grate as usually made and installed, an effort to prevent fuel being discharged over the back end by running short fires, is accompanied by an increase of the excess of air that often overbalances the fuel saving.

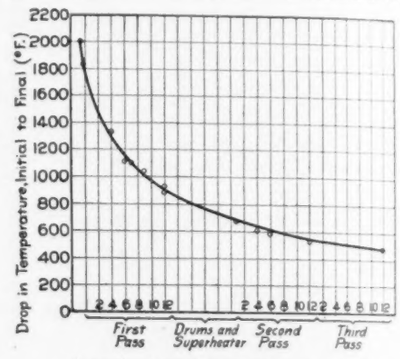

Fig. 7. Drop in Gas Temperature in Babcock & Wilcox Boiler of 400 HP.

The entrance of air at the back end of the grate is, strictly speaking, a leakage; its entrance is by way of openings at the side of the stoker, between the top and bottom chain and under the traveling grate, and into the furnace by way of the opening between the bridge-wall and the end of the grate. For this leakage at the back of the fire there are two remedies; one is to make the opening for the discharge of the refuse only large enough to allow the ash to pass out, and keep the end of the fire in contact with the bridge-wall. This opening may be restricted by building the brick bridge-wall the required distance above the grate, or by building into the point of the wall a metal box or pipe through which water circulates for the purpose of keeping it cool. The disadvantages of the brick wall are that the clinker readily adheres and makes trouble, and that the life of the brick at the lower edge is very short, requiring frequent and expensive renewal. The size of the opening is a matter that is necessarily unsatisfactory, because the amount of ash in the coal will differ and the opening must be large enough to accommodate the largest amount, consequently being too large when ash is low. The performance designated as example No. 1 was obtained with the brick wall described, and owing to an extremely large amount of ash in the coal the effect was to close the opening at the end of the grate largely with ash rather than with fuel, resulting in a comparatively small loss to the ash pit. Of these two means for keeping the air from leaking into the furnace by maintaining a joint between the end of the fire and the bridge-wall, the water back is the most satisfactory.

The other method of stopping air leakage at the end of the fire consists in closing the openings at the sides of the stoker, and between the bottom chain and the floor under the stoker, and between the upper and lower chains. With this scheme the air leakage is avoided without keeping the fire against the bridge-wall. It was with this method that the performance designated as example No. 2 was obtained; the large capacity was owing to the use of washed coal from the Wilmington district of Illinois. At the present time the best means to offer for the remedy of the faults at the back end of the fire is to seal off the leaks as mentioned in the second method, and the use of

the water-back, located as close to the grate as practicable. The latter performs an important office, inasmuch as it is an insurance against carelessness in running the fires over the back end of the grate.

The foregoing has treated only of the excess of air coming from the back end of the grate, but it does not entirely cover the subject of excess of air. With the furnace of the A type, 12% CO_2 is about the maximum under any condition. This is also true of the tile-roof furnace unless the fire is so operated that a considerable excess of volatile combustion is evolved at the front end of the fire and mixed with the excessive air from the thin fire at the back. But the evolution of an excess of volatile combustible requires either a thick fuel bed or a low draft, and it appears that the thickness of fuel bed and strength of draft are features of importance.

With chain grates as generally installed and operated, all other conditions being the same, a reduction in the draft over the fire results in increased efficiency and reduced capacity. On the other hand, an increase in draft over the fire increases the capacity, but reduces the efficiency. In the plant mentioned as having the tile-roof furnaces, drafts over the fire range from 0.15 to 0.45 ins. of water, but the attainable depth of fire, height of coal in the hopper and speed at which the grate travels, are the same for each strength of draft. It is entirely reasonable to assume that if 0.15 is strong enough, 0.45 is too strong; likewise that if 0.45 is right 0.15 is too low; and it is apparent that the dimensions of the stokers and the various drafts are not in proportion to each other. In this plant the high efficiencies are always obtainable with the lowest drafts, and the highest capacities with the strongest drafts.

It is the general tendency to seek a strong draft over the fire with chain-grate stokers, and for this purpose induced mechanical draft apparatus and tall chimneys are employed; but suction drafts may be so strong as to cause such an excess of air to flow through the coal in the hopper as to prevent the fuel from igniting. It is possible that a moderate suction above and a pressure above atmosphere under the fire will give the most satisfactory results when large capacities are required.

Loss of combustible in the refuse with chain-grate stokers has been observed as low as 1%. With the tile-roof furnace, complete combustion with little or no excess of air has been secured, and if such desirable furnace conditions are combined with the performance of boiler No. 3, it will make an important improvement over the best prevailing practice. It is probable that this is the most efficient boiler of which there is any record. About the highest efficiency reported is that of a Thornycroft boiler by Professor Kennedy, showing 86.8% of the heat absorbed when evaporating 1.24 lbs. of water per sq. ft. of heating surface per hour with a condition of combustion about the same as that with No. 3; under these conditions the gases left at 41° F. above steam temperature. With, however, an evaporation of 3.2 lbs. of water per sq. ft. of heating surface and a somewhat better combustion, the gases left at 165° F. above steam temperature. In the case of boiler No. 3 the gases left at 92° above steam temperature when evaporating 4.17 lbs. of water per sq. ft. of heating surface. No. 3 is a more efficient boiler than A, but owing to its design, there is no favorable location for a superheater. With the A-type, the design affords an excellent location, which is sufficiently removed from the excessive furnace temperature, and at a point where it is high enough to ensure the desired effect.

There is one feature of the tile-roof furnace previously mentioned, which is of considerable importance. It is the protection afforded to the low row of tubes of the boilers designated as Nos. 1 to 3. It has been the maker's practice to use the tiles shown by Fig. 6. This leaves half of the bottom row of tubes exposed to the full-furnace action; it does not matter that there are many hundreds of feet of surface in the boiler above, because the gases do not come in contact with this surface until after leaving the furnace. As with an economizer, the boiler is heated first. Applying this illustration to the surface exposed to the fire, the 110 sq. ft. over the furnace may be assumed to the boiler surface. This would mean that there are about 1.5 sq. ft. of heating surface per square foot of grate; the result is that the tubes in the bottom row become blistered, bent out of line and fail, owing probably to the area of the tube not affording sufficient water supply. But with the tiles in place, the tubes in the low row remain as straight and in as good condition as those in the uppermost row.

IRRIGATION STUDIES IN THE HUMID SECTIONS OF THE UNITED STATES.

A brief account of irrigation studies by various persons in the humid sections of the United States is given by Mr. Elwood Mead, M. Am. Soc. C. E., in his "Review of Irrigation Investigations for 1902," which has been reprinted from the annual report of the Office of Experiment Stations, U. S. Department of Agriculture. Mr. Mead says:

There are few sections in the United States where at some time during the growing season a drought of greater or less severity is not experienced each year, and where the application of water, if for a brief period only, would not secure largely increased yields. It remains to be determined, however, whether this kind of irrigation will pay. The answer to this question is of enough importance to the agriculture of the country to warrant the aid of this investigation. The number of farmers who are establishing experimental irrigation plants is already large, and the advice given by this department during the last season affected the expenditure of several thousand dollars. It prevented some serious mistakes, which would have cost more money than was appropriated for the investigation. Without this advice nearly all of the pumping plants installed would have had too small a capacity and the result would have been a loss of the investment and of the farmer's time and an erroneous conclusion as to the value of irrigation. In addition to this general assistance, systematic studies of the possibilities of irrigation in the humid portions of the United States are now being carried on in Wisconsin, Missouri, and New Jersey in coöperation with the State agricultural experiment stations of those states. The results in 1901 were all in favor of irrigation because the season was dry. The results in 1902 were less favorable because the season was wet.

NEW JERSEY.—The report of Prof. Edward B. Voorhees, director of the New Jersey Agricultural Experiment Station, who has charge of investigations in New Jersey, reaffirms his previous statement that an irrigation plant will pay in connection with trucking and fruit growing and will be of service every year for one or more crops. His investigations have shown that irrigation on a small scale is entirely practicable and profitable, with plants costing from $150 to $600 and capable of irrigating from 1 to 10 acres. So far as the section dealt with by Professor Voorhees is concerned, it is practically settled that in intensive farming irrigation is profitable. The problem which still remains to be studied is whether it is practicable to utilize water by gravity systems in those districts where the soil is poor, but well adapted to sweet potatoes, small fruits, and other vegetable crops.

WISCONSIN.—The sandy lands around Stevens Point, Wis., were chosen for the beginning of the investigations in that state, the purpose being to determine what effect irrigation would have on the sandy soils, which without an additional water supply have little agricultural value. The investigations of 1901 were explained in the report of last year. The soil here contains so little clay that water can not be carried through open ditches. Last year a canvas hose was used in distribution, but was not satisfactory, and was replaced this season by a 10-in. main of sewer pipe, the canvas hose being used for distribution from this main. The rainfall this season was unusually heavy. Nevertheless, most of the crops were irrigated once or twice during the latter part of the growing period. Because of the leachy character of the soil, the heavy rainfall of May was not retained, and irrigation under these conditions gave an increased yield. The water for the lands irrigated is raised by a gasolene pumping engine, the lift being 33 ft. The following were the results:

Early potatoes were irrigated once, on Aug. 8. The water used covered the land to a depth of a little over an inch; 3.44 gallons of gasoline were used in pumping the water for each acre, the expense being $0.43 for fuel, $0.25 for preparing the ground, $0.15 for applying the water, or a total cost of $0.83 an acre. The irrigated acres yielded 93 bushels per acre, the unirrigated 81, or a gain for irrigation of 12 bushels. On unmanured land the irrigated acres yielded 63 bushels, the unirrigated 58, or a gain of 5 bushels to the acre. Late potatoes were watered twice, the water used covering the ground to a depth of 4.07 ins. The expense for fuel was $1.73 an acre; for applying the water, $0.67; preparing the land, $0.25; or a total cost of $2.65 an acre. On manured land the increase was 17 bushels per acre, on unmanured land, 6 bushels per acre. The potatoes were sold at $0.20 a bushel, so that on the manured crops there was a profit, and on the unmanured ones a loss.

Prior to the receipt of the report of this year's investigations, it had been decided that the experiment at Stevens Point should not be continued, because of a belief that the same expenditure in other localities and along different lines will give results of more general value. As has been before stated, the fundamental question in the East is whether or not irrigation will pay, and in order to answer this the first study should be made in the growing of high-priced products on productive land, where it is most likely to be beneficial. The cost of preparing to irrigate does not justify irrigation experiments on land which has little value. The best results will most likely be had where the value of the crop is great, and where an increased and certain yield is important.

MISSOURI.—The investigations in Missouri have been under the immediate supervision of Prof. H. J. Waters, director of the Missouri Agricultural Experiment Station. A storage reservoir has been built to furnish water, which will be used chiefly in the irrigation of fruit trees and vines, and in stimulating the growth of nursery stock. The results indicate that such irrigation will pay. The orchard and small fruits watered during the drought of 1901 gave largely increased yields in 1902, showing that the effect of irrigation is not limited to the year the water is applied. Professor Waters believes that in Missouri an expenditure of $200 an acre can be profitably made for the purpose of irrigating nursery stock.

THE SOUTH.—It is in the South, however, that the greatest progress is being made in the installation of small irrigation plants, and it is here that the conditions promise the most satisfactory results. During the past season this office has furnished advice as to the installation of pumping plants by farmers, and there are a number of requests on file for this kind of assistance in the spring of 1903. Farmers engaged in truck farming in the vicinity of Atlanta, Ga., and Birmingham, Ala., are manifesting much interest in this question.

The remarkable increase in the production of rice along the Gulf coast has made it desirable that the irrigation problems of this section be systematically studied. Many of the farmers know nothing of the methods of applying water to crops. Many unsolved questions confront the manufacturers of pumping machinery and those who buy and operate it. There is need to know how much water is required, how it can be distributed with the least loss, and used to the best advantage. In addition, the drought of 1901, which continued unrelieved throughout the season of 1902, has shown the need of an early determination of how much water the streams of this section can be relied upon to supply, and the enactment of some laws for the establishment of rights to this supply and for their protection in times of scarcity. Otherwise there is danger that this development will continue beyond safe limits. During the past season so much water was pumped from the bayous and streams that in some instances the current was reversed. There was not enough fresh water coming in from above, and the shortage was made up by salt water flowing inland from the Gulf. The use of brackish water caused the injury of many crops, and some were destroyed. If this is to continue, a permanent injury to the soil will be the result. The agents of this office gathered samples of this water, which were shipped to the Bureau of Chemistry for analysis, and prompt warning was given to companies that the water was becoming too salty for safe use.

A SHIP'S PUMP HAS BEEN INVENTED by G. Foster Howell, editor of the "American Shipbuilder," and the only cost of its operation is the lubricant required. It consists of a normally horizontal lever with a vertical pump rod at each end, and a weighted pendulum at the center. The roll of the ship swings the pendulum and drives the pump rods.

THE NEW KEW BRIDGE across the Thames River, England, was formally opened on May 20. The bridge joins the counties of Middlesex and Surrey from Brentford to Kew, and is the third to be erected on the site. The first bridge was a timber structure and was completed in 1759; the second was a masonry arch structure completed in 1789. The present or third bridge consists of three elliptical arches; the center arch has a span of 133 ft. and the side arches spans of 116½ ft. each. The two piers are each 18 ft. thick at the level of the skewbacks and 38 ft. at the foundations, which are carried down into the solid London clay to a depth of 18 ft. below the bed of the river. The bridge has a 36-ft. roadway and two 9½-ft. sidewalks. The engineers of the bridge were: Sir John Wolfe Barry and Mr. Cuthbert A. Breveton, and the contractors were Easton Gibb & Son, of London.

A PROCESS FOR BRINGING DOWN HUNG CHARGES in blast furnace or cupola work, or for cutting through any body of iron, steel, etc., was reported by Mr. Menne at the recent meeting of the "Verein Deutscher Eisenhuttenleute," at Dusseldorf, Germany. The process consists in using an oxy-hydrogen flame to rapidly heat a small spot of the piece, and when it reaches white heat shutting off the hydrogen, at the same time increasing the pressure on the oxygen (up to as much as 30 atmospheres). The burning of the iron by the oxygen rapidly makes a hole through the piece, and the high pressure blast blows the liquid material out of the hole, so that horizontal and vertical holes may be made with equal facility. Copper is not affected by this method, so that in a combination iron and copper plate it is possible to remove portions of the iron half without affecting the copper backing. The process is owned by the Köln-Müsener Mining Co., of Kreuzthal, Westphalia.

AN EXPEDITION TO LABRADOR will start from Boston, Mass., in the latter part of June of this year, under the leadership of Mr. Willard Glazier, of Albany, N. Y. From Hamilton Inlet, on the east coast of the peninsula, the party will ascend the Northwest River, cross the divide to the head of George River, and follow the latter to Ungava Bay. It is expected that valuable information will be secured as to the geography of the little known portions of Labrador.

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ADVERTISING RATES: 20 *cents a line. "Want" and "For Sale" notices, special rates, see page XXIV-XXIX. New copy for standing advertisements should be received one week in advance of publication; new advertisements, Monday morning. The pages containing "Want," "For Sale" and "Proposal" advertisements are held open until Wednesday noon.*

We recorded in our issue of May 14 the offer of $45,000 in prizes for the best design for canal lift works, to overcome a difference of level of 118 ft. on the canal between the Danube and the Oder rivers. One of our contemporaries has evidently run across the same item in the German technical papers and announced to its readers in its issue of last week that "A prize offer for a lifting pump is published by the Austrian Minister of Commerce."

Of such are the pitfalls that await the translator from a foreign language who is unfamiliar with technical terms.

Incidentally we may note that particulars concerning the competition can be obtained in the United States of the Austrian embassy in Washington, or of the Austrian consulates in New York, Philadelphia, Pittsburg, Chicago or San Francisco.

A question that appears to be arousing some discussion just now relates to the exact definition of the terms "civil engineer" and "civil engineering." On the one hand we are told that the term "civil engineer" still denotes, as it did originally, the engineer who has to do with civil works as distinguished from military works. On the other hand, it is contended that civil engineering has come to be actually only one branch of the profession. In view of these conflicting opinions, it is of interest to see what the "Century Dictionary" has to say on the matter. We quote as follows:

ENGINEER.—A person skilled in the principles and practice of any department of engineering. Engineers are classified, according to the particular business pursued by them, as military, naval or marine, civil, mining, and mechanical or dynamic engineers.

CIVIL ENGINEERING.—That branch of engineering which relates to the construction or care of roads, bridges, railroads, canals, aqueducts, harbors, drainage-works, etc.

It will be noted that civil engineering is specifically defined as a *branch* of engineering, and in the same paragraph definitions are given of electrical, hydraulic, mechanical, mining and other branches of engineering work.

We do not think it can be seriously contended by any one that these definitions are incorrect. They represent actual facts, conditions as they are, and not as one may wish them to be. In the offices of a railway company, for example, the department of Civil Engineering has to do with the construction of the road and its maintenance, with bridges, culverts, land surveys, etc. The officer who has to do with the testing of machinery, locomotives, etc., is called a mechanical engineer and not a civil engineer. Similarly in the navy, the civil engineers of the navy have their sole field in the bureau of yards and docks. In the engineering schools, too, civil engineering is as much a special course as is mechanical or electrical or mining engineering.

It is not true, therefore, as has been recently stated, that "the generally accepted definition of a civil engineer is one who directs the sources of natural power to the service of mankind."

It is claimed also that because the American Society of Civil Engineers admits to its membership engineers engaged in any branch of engineering work, it is therefore representative of the profession at large. The facts, however, do not support this contention. While it numbers among its members a few prominent representatives of the electrical, mining and mechanical branches of the profession, the rank and file of the membership are engaged in purely civil engineering work. Another excellent indication is the character of the Society's "Transactions." Examine the papers read before the Society and they will be found to relate almost without exception to the work of civil engineers. Look through the volumes for literature on electrical engineering or mechanical engineering or mining engineering and little or nothing will be found.

There is good reason for this. The man who takes the trouble to prepare a valuable professional monograph wants to present it before an audience who can comprehend and appreciate his work. Even under present conditions in the American Society of Civil Engineers, the complaint is frequently heard that important papers read there receive little or no discussion, and this is one symptom of a condition which is bringing about the organization of societies devoted to special branches of civil engineering work, such as the Railway Engineering Association, and the societies devoted to municipal engineering work.

THE DESIGN AND COST OF SLOPE-WALLS, INCLUDING COST OF QUARRYING.

A slope-wall is practically a stone block pavement laid upon a sloping face of earth to protect it from erosion. The "wash" of passing boats in canals makes necessary some such protection of the earth in certain places. The beating of waves upon the sides of a reservoir or small lake acts in a similar manner, and a slope-wall is usually provided to resist the erosion. The concave side of a river bank is occasionally protected by slope-walling, with perhaps a line of piling at the toe of the wall.

A dry slope-wall, it will be seen, is an engineering structure often used, although very little exists in print as to its design or cost. Since the forces acting upon a slope-wall are not readily measurable, the design is an art, and not a science. Recorded experience of others, personal experience of the designer and common sense should govern the design.

The oldest slope-walls on the Erie Canal were made of cobblestones rammed solidly into the bank, and placed so that the stones touched one another. Cobbles for this purpose were gathered from fields or creek beds, and ranged in diameter from 4 ins. to 12 ins., the average being about 6 or 8 ins. These cobble slope-walls while not as handsome as those made of dressed quarry stone were in fact more durable, for the shales and limestone ledges along the route of the Erie Canal furnish stone more or less subject to weathering. Cobbles, or "hardheads," on the contrary, are often granitic and always tough.

Slope-walls made of quarry stone are built as shown in Figs. 1 and 2. The stones are split with plug and feathers, then roughly dressed with a hammer, and placed in the wall on edge, just as brick or stone block are placed in a street pavement. The longest dimension of the stone is laid parallel with the axis of the canal or river. In some of the earlier walls, huge slabs of stone were laid flatwise just as sidewalk flagging is laid, but such stones are apt to settle unevenly and tilt up so that a passing boat or moving ice will displace them entirely. Moreover it is practically impossible to bed very large stone properly, since ramming has no effect. Experience, therefore, has shown the necessity of splitting up slabs into blocks readily laid and bedded by hand; and it costs no more in the end to build walls in this way, for the cost of handling with a derrick and cost of frequent moving of derrick more than offset the cost of splitting the stone. It is customary on the Erie Canal to always provide a lining of gravel (Fig. 1) back of the wall. This lining serves a twofold purpose, it makes it easy for the workman to properly bed jagged stone, and it further adds to the protection of the subsoil from wash. Waves beating through the joints in the slope-wall strike this gravel which is not easily displaced, and do not reach the subsoil with sufficient force to displace it. It is our opinion that this gravel lining is one of the most important and necessary features of a well-made slope-wall. Crushed stone, of course, would serve equally well or better, but usually the cost is more than for gravel. There are places where broken stone costs less than gravel and in such places it should be used.

On rivers or reservoirs, subject to wide fluctuation in water level, the gravel or stone lining for the paving is even more necessary; for there the surface rain water, flowing down over the face of the slope-wall, will cut rivulets beneath it unless proper lining is provided. Embankments are usually so designed as to prevent much rain water from flowing over the slope-wall face, as shown in Fig. 1, where the towpath is seen to have a slope away from the canal. In diking a river the same form of top slope is usually provided where a slope-wall is to be laid; but in protecting a natural river bank it is often impossible to entirely prevent rain water from flowing over the face of the slope-wall. Ditches should be dug to divert the rain water, which is then carried in a pipe culvert through to the river. Ditches, however, are apt to fill up with washed-in earth, so that in any event a substantial lining of gravel should be placed back of the slope-wall, in order to guard against erosion by rain water. A thickness of gravel lining of from 4 to 8 ins. will suffice, 4 ins. being ordinarily enough.

Passing to the thickness of the stone slope-wall itself, we find a range of from 6 ins. to 24 ins. with 12 to 16 ins. most commonly used. The Chemung River, near Elmira, N. Y., is a stream about 600 ft. wide and 20 ft. deep in times of high water. At one place on this river a slope-wall 24 ins. thick was built by the State, and a few miles away another had been built 12 ins. thick, both of a shaley limestone. Both walls have served for years, except in places where the piling at the toe has been undermined. The 24-in. wall was evidently an extravagant design, and not justified by the conditions, particularly as the lighter wall had been in service some years before the construction of the 24-in. wall was begun. Because a river is occasionally a raging torrent it does not follow that the floating debris or ice will displace the small stones of a well-laid slope-wall. As a matter of fact, each stone is held by the weight of stones above, even when laid on a 1½ to 1 slope, and a stone is pried out of a slope-wall with great difficulty. We believe that ordinary brick laid dry as a slope-wall pavement will protect a river embankment perfectly, provided the subsoil does not become undermined. In slope-wall masonry, on river embankments subject to blows of ice and logs, a thickness of 8 to 10 ins. seems an advisable minimum, for some erosion and settlement of the subsoil or lining must be provided for. On reservoirs or canals a less thickness may be used where blows from boats are not frequent. But as above stated 12

ins. is very often specified, and as will be seen later, it is not an extravagant depth. Having fixed upon the depth of stone to be used in the wall, the thickness and length remain to be determined. A minimum thickness of 4 ins. is usually specified. As a matter of fact, except for appearance sake, thickness is not an important factor. An engineer who is fond of seeing coursed masonry will often require that the slope-wall be laid in courses of a specified minimum and maximum thickness. It costs money to dress the stone to lay in such courses, but for appearance sake, near a highway, such expense may be justified. Ordinarily it is not justifiable. Slope-walls are built for protection, not for beauty. At best they are beautiful only in the eyes of an engineer.

If any definite minimum thickness is specified, it should be governed by the stratified thickness of stone in the nearest quarry. If the quarry is thick-bedded limestone, then it is safe to omit any minimum thickness requirement; for to split into thin slabs with plug and feathers is expensive, and the contractor will surely not split the stone thinner than the maximum thickness specified. If the quarry stone is thin-bedded, as shaley limestone and some sandstones are, a minimum thickness of 3 or 4 ins. may be named. A maximum thickness of 10 or 12 ins. is a reasonable requirement. A minimum length of 12 ins. is often specified, and is not unreasonable, for slabs are readily broken with a hammer to almost any desired length. There is no objection to stones up to 24 ins. in length.

Slope-wall paving is "laid to break joint," as shown in Fig. 2; and it is well to so lay it, because if the toe is washed out, this breaking of joint enables the wall above to span the space, and so prevents rapid crumbling away of the wall. However, specifications are often drawn with absurd refinement as to this bonding; the least admissible number of inches of bond is named, and altogether the wall is treated as if it were to be a bridge pier, or arch, or other necessarily strong structure. To simply require that the stones shall be laid so as to break joint is a sufficient requirement for slope-wall work.

We come now to the feature of the specifications that makes a wall cost little or much—the allowable maximum width of bed and end joints. Specifications sometimes name ½-in. joints to the full depth of each stone. Such work as we shall see costs twice as much as under the more reasonable requirement of 1½-in. joints, carried back 4 ins. from the face beyond which the stone may fall away to a wedge shape. To call for joints of less than 1½ ins. is justifiable only where well coursed slope-walling is desired for appearance sake. Wall with 1½-in. maximum joints serves the purpose of protection from erosion, and any expense incurred in better dressing is merely "for looks."

In laying a slope-wall, "frames" or "profiles" should be set about 20 or 25 ft. apart, as shown in Fig. 3. Stakes are driven as shown, and a 1 × 4-in. profile-stick of timber is nailed to the stake at the proper grade, as determined by the Y-level. The workmen then stretch a string from the bottom of one frame to the bottom of the next one, and thus have a line to which they can accurately lay the face of the slope-wall. Never allow a workman to attempt to lay slope-wall without such frames and a cord to guide him; for without such guides he will surely lay a wall with humps and hollows. Another point in practical laying is to always incline each stone slightly uphill. Do not try to set it exactly at right angles to the surface of the ground, for an endeavor to do this results in a wall like that in Fig. 4, where the stone are in steps.

The stone are split with plug and feathers and hammers in the quarry, hauled by wagons and dumped at the top of the embankment, as in Fig. 3. Laborers then throw the stones down to the slope-wall masons, who roughly scabble and lay them, filling in the chinks back of the face with spalls and gravel lining. An intelligent laborer can soon learn to lay common slope-wall, but skilled slope-wall masons, if available, usually lay a better-appearing wall at less cost. Sharp-pointed stones like A, Fig. 5, should ordinarily not be allowed; but stones like B, that are roughly dressed, 3 or 4 ins. back of the face, and then fall away so as to leave a wide end joint as shown, are not objectionable, provided these joints are filled with spalls and gravel.

Before passing to a consideration of costs, a word should be given as to protecting the toe or foot of the wall. In canal work it is customary to lay a 12 × 12-in. toe-timber or stick, as shown in Fig. 3. Since timber continually submerged does not rot, and since frozen timber in the winter when canals are closed does not rot either, this design is not objectionable for canals. However, we question the necessity of using a toe stick at all under ordinary conditions in canal work. In river work, a toe stick, resting against piles driven 5 ft. c. to c., is often used. In some cases the toe stick is done away with entirely and a line of close-driven piles substituted, which is a very expensive solution of the problem and not altogether satisfactory. Piling on the concave bank of a river seems to hasten rather than retard undermining. A brush mattress is a better toe protection under such conditions, and heavy rip-rap is still better where the brush is alternately wet and dry.

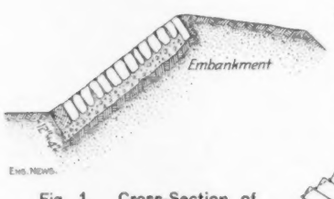


Fig. 1. Cross-Section of Slope-Wall.

Fig. 2. Face of a Good Second-Class Slope-Wall.

Fig. 4. Improperly Laid Slope-Wall.

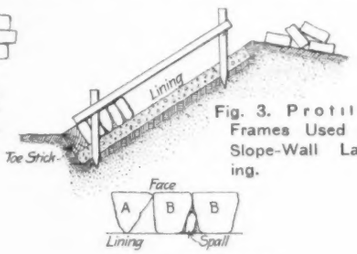


Fig. 3. Profile-Frames Used in Slope-Wall Laying.

Fig. 5. Showing Proper and Improper Dressing of End Joints.

COST OF QUARRYING.—While there is a wide range of cost of doing any particular kind of work, it is possible to so separate the items of cost as to enable the making of a close estimate by any one possessed of a little experience. The following are actual costs of work done by a member of the editorial staff of this journal:

The quarry required very little stripping, and was located on a side hill, 2½ miles from the work. The stone was a thin bedded limestone, rather shaley, and was barred and wedged out with the use of little or no powder. There was very little plug and feathering as the stone split readily under the hammer. Common labor was employed, the only skilled man being the foreman, who worked with the men.

140 wagon loads of stone, each load measuring 2 cu. yds., corded upon the wagon, and 1.55 cu. yds. laid in the slope-wall, making a total of 220 cu. yds. in the wall, were quarried and loaded by five men (including the foreman) in 20 working days of 10 hours each, or at the rate of 2.2 cu. yds. of slope-wall quarried per man per day. Laborers received $1.50 a day and foreman $2.50, so the wages averaged $1.70, which, divided by 2.2, makes the cost nearly 80 cts. per cu. yd. for quarrying and loading the stone. Each driver helped load and unload his wagon, and hauled 4 to 5 loads a day. A team and driver received 70 cts. a load for hauling (5 miles round trip) over a good hard gravel road with no upgrades; so the cost of hauling was about 45 cts. per cu. yd. of slope-wall, making a total of $1.25 for the stone delivered at the work. A quarry rental of 10 cts. per cu. yd. was paid for the stone. To estimate the cost of loading and hauling for other distances the following observations were made: Two laborers working quite deliberately handed up the stone to the driver, who stacked them on his "stone rack" (3 × 11 ft.), or wagon box without sides other than a strip of 4 × 4-in. timber. It required 15 mins. to load a wagon with 2 cu. yds. measured on the wagon, or 1.55 cu. yds in the slope-wall. The driver alone would unload his wagon at the dump in 7 mins., by simply rolling the stone off.

The team traveled at a speed of 2½ miles an hour, or 220 ft. a minute, at a walk, and generally trotted part of the way back to make up for lost time at both ends. With a short haul, or over soft roads trotting would have been out of the question; and over very soft earth roads with occasional steep pulls a load half as great as the above is the maximum. On another similar contract 750 cu. yds. of slope-wall were quarried at a cost of $1.10 per cu. yd., the stone being a "grit" or shaley limestone, quarried by laborers at $1.50 per day of 10 hours. The haul was 1¾ miles from quarry to wall and 6 trips a day were made by each team, hauling 1¾ cu. yds. each trip as measured in the wall, at a cost of 35 cts. per cu. yd. for hauling. This stone, therefore, cost $1.45 per cu. yd. delivered.

COST OF LAYING SLOPE-WALL.—In laying 750 cu. yds. of "second-class" slope-wall, 12 ins. thick, joints 1½ ins. as a maximum, stone allowed to fall away 4 ins. back of face, not laid in courses, but an excellent wall in appearance and in reality, the cost was as follows: The first few days, using new hands, intelligent laborers, each man laid 2½ cu. yds. at a cost of 60 cts. a cu. yd., wages being $1.50 per 10-hour day. Later these men readily averaged 3 cu. yds. per day. Some skilled slope-wall layers were imported and received $2.50 per 10-hour day. These men readily laid 5 cu. yds. each per day, one laborer to every four slope-wall layers acting as a helper to deliver stone. Thus 600 cu. yds. of slope-wall were laid in 130 layer-days and 35 helper-days, half of the layers being skilled men, and half common laborers. There was no foreman in constant attendance, as each man's work between the frames was easily measured up, and his daily progress thus known. A portion of the work was sublet at 50 cts. per cu. yd. to two of the skilled slope-wall masons who had each been averaging 5 cu. yds. a day. From that time on each averaged 7½ cu. yds. of wall daily! Skilled men like these under subcontract will lay 10 or even 12 cu. yds. of a somewhat rougher slope-wall in 10 hours. On another contract where the wall was 16 ins. thick, 4 masons at $2.50 and 4 laborers at $1.50 averaged 60 cu. yds. of fair slope-wall per 10-hour day. Work was scarce, and one of the masons was the subcontractor himself, and received 30 cts. per cu. yd. Assuming 50 cts. per cu. yd. as a fair average cost for laying good "second-class" slope-wall and $1.25 to $1.50 for cost of stone delivered, we have a total cost of $1.75 to $2.00 per cu. yd. in place. The average contract price for slope-wall on the Erie Canal deepening in 1896-7 was $2.50 per cu. yd., wages being as above given. Slope-wall laid in courses, with close joints the full depth of the wall, no course less than 6 ins. thick—a sand-papered job—was let for $4.50 per cu. yd. under conditions where $2.50 was a fair price for good ordinary slope-wall. The actual cost was not far below the contract price for stone plug and feathered to size cost delivered $2.50 per cu. yd., and laying cost $1.25 per cu. yd. Gravel lining in both cases was paid for separately, the contract price along the Erie Canal averaging 90 cts. per cu. yd. of lining in place. The actual cost of this lining is of course figured as for any earthwork, an allowance being made for spreading it on the face of the embankment after dumping it. To spread it most expeditiously it will pay to make a wooden chute into which the gravel is shoveled from the wagons, a shoveler helping the driver to unload. Two men will unload 1 cu. yd. in this way in 10 minutes, if they work as they should. The driver then has a rest on his return trip, at the end of which it is well to provide an extra wagon, which has been loaded

during his absence. It takes only 1½ mins. to change the team from the empty to the loaded wagon. Since 1 to 1¼ cu. yds. of gravel constitute a load, since teams easily travel 220 ft. a min., or 2½ miles an hour at a walk, and since a laborer can load 18 to 20 cu. yds. of gravel in 10 hours, we have all the factors necessary to compute the cost of loading, hauling and unloading. There will be very little work in spreading the gravel where a chute is thus used, 2 to 5 cts. per cu. yd. covering this item of cost.

From the above data the cost of a good slope-wall, where thin-bedded limestone or sandstone is available, may be calculated with accuracy for any given length of haul at any given rate of wages. Slope-wall work is peculiarly adapted to subletting, or each man may be given a daily "stint," so that shirking is difficult even with no direct and constant supervision.

LETTERS TO THE EDITOR.

The Engineering Building of America: One More Impression of the Situation.

Sir: The present opportunity for the American Society of Civil Engineers is welcome to those who favor a natural development of American institutions.

Some cherished traditions, rules and habits, but concerning which there has by no means been unanimity, may indeed be in danger of being swept away; but undoubtedly, with the larger, broader life, larger and better ideas will take their place; ideas native to the soil on which they are to grow. I say, therefore, trust the future; especially in America. The most plausible argument of Mr. Croes' letter is the financial one, but I think it can be answered. Says Mr. Croes (Eng. News, p. 479):

> In the scheme of coöperation proposed . . . all the recipients of the gift of a house are designated as "tenants, in common, share and share alike." . . Here then is one successful corporation which has both cash and credit . . . asked to go blindly into a partnership with four other concerns, which so far have not displayed their abilities in that line . . . Its own property must be sacrificed and the proceeds put into a speculation in which they will be liable to confiscation. . . .

Not at all, if its affairs are to be managed with ordinary prudence. Nothing easier than to be poor, before going into a limited liability company, to all the intents and purposes of that company.

If the American Society of Civil Engineers is now worth $250,000 and is asked to enter "share and share alike" into a partnership with four tramps, let it put its $250,000 into the hands of trustees for its own proper use and benefit, and then gaily and unconcernedly enter the limited partnership or company. It might even be argued that the strong stockholder or partner would thus stand a good chance of eventually controlling more than "share and share alike" of the property, if that should appear proper and desirable. But at all events he need not fear his tramp brethren. He may welcome them, and unreservedly give them a chance to become his equal in all essential attributes.

Clemens Herschel,
2 Wall St., June 5, 1903. M. Am. Soc. C. E.

The Union Engineering Building.

Sir: Replying to your communication asking for an expression in re the Union Engineering Building project, I will say I am heartily in favor of the acceptance of Mr. Carnegie's offer, and I believe that the universal sentiment of the engineering profession is that it should be accepted and that that sentiment prevails among the members of the American Society of Civil Engineers.

I have read with much interest the communications published in the Engineering News, including that of J. J. R. Croes, and I doubt very much if there are many members of the American Society of Civil Engineers who endorse Mr. Croes' views.

If there is any thing that is needed in the engineering profession, it is association and combination, and the American Society of Civil Engineers does not, and cannot hope to, represent the engineering profession as a whole. As illustrations of what organization will do for a profession I would call attention to the American Institute of Architects and what it has done for the architectural profession; to the Bar Association of the City of New York and what it has done for the legal profession; and to the wonderful organization of the Catholic Church as compared with the individual elements composing the Protestant Church.

I believe in organization and of the affiliation of the industrial societies and of the union of the engineering associations of the country.

The opposition to the union of the four national societies with the Engineers' Club is confined to a small number of the members of the American Society of Civil Engineers, whose feelings are betrayed in the letter of Mr. Croes and the causes of which are apparent. It is to be hoped that pique, a fear of "monarchies," a wish for exclusive control and patronage, the pride and extreme satisfaction of being well-to-do and having credit even though the subject of charity, the self-esteem of high qualification for membership, and the business policy of making the most out of a good investment, will not dominate the feelings and acts of the majority of the members of the American Society of Civil Engineers.

As some correspondent has stated, it will be a great benefit to the young men of the profession, and as the membership of the American Society of Civil Engineers is now represented largely by young men, it is safe to say that, if the question be submitted to a vote of the society and is not made the subject of a convention vote, the plan will be heartily endorsed. Respectfully yours,

John C. Wait.
220 Broadway, New York, June 3, 1903.

Right and Left in Structural Work.

Sir: I wish to thank you for the excellent answer to my query in Engineering News of May 21. But your answer did not quite reach the point which my question was framed to bring out, viz., the abuse of the notation "Right and Left with respect to . . . only."

A draftsman and a checker once disagreed as to the meaning of this notation in a particular case, and both asked my opinion; I was compelled to admit that both were right though they were in disagreement. You will find in at least half the cases where this notation is used that there are two or more possible and reasonable solutions. Suppose a column composed of two channels, latticed, with base plate and unsymmetrical cap, e. g., a beveled cap, with two different connections "X" and "Y" on the outside of the web of one channel unsymmetrically arranged with reference to all center lines of column. Suppose it marked

1 column C 3 R } {Right and left with respect to con-
1 column C 3 L { } nections "X" and "Y" only.

Then column C 3 L may be made in three different ways: (1) Taking for axis of R & L a plane parallel to plane of latticing and half way between flanges of channels. (2) Taking a plane parallel to web of channel and half way between channels. (3) Taking a plane parallel to backs of base angles and half way between backs of angles. This transfers each connection.

(1) to opposite side of same [,
(2) to other channel,
(3) to opposite end of same [,

the rest of the column remaining unchanged.

We have three quite different columns that can be made, each one in accordance with above detailing.

Is it not true that the use of the term above mentioned where the axis of revolution is not clearly defined is one of the abuses of which you speak?

The case cited by you (Eng. News, May 21) is, to my mind an example of correct use where the location of the axis would be at once apparent to any skilled workman.

"Draftsman."
Pittsburg, Pa., May 30, 1903.

(Our correspondent is quite right in the above. In cases like the one mentioned it is possible to produce more than one "left-hand" object which will answer the notation used. In some cases of this sort the nature of the object, and the workman's general knowledge of the arrangement of the job to which the part belongs, or a study of the erection drawing, will be a sufficient guide to the correct selection of the plane of revolution or rather interchange. But many other cases occur in which it is not clear from the drawing just how the interchange shall be made. Our correspondent suggests that the axis of interchange be marked. While this is, ultimately, sufficient for the purpose, we think it might often not be readily interpreted by the workman, and this might lead to error or at least loss of time. The better plan to follow in such a case is to make an additional sketch or partial drawing of the part where the interchange is to be made; that is to say, in the above example of a column which is to be made "one right, one left, with respect to connections X and Y only," an elevation of the affected part of the column, showing the connections for the "left-hand" column, should be added to the drawing.

The matter of "right and left" is often not clear enough in the mind of the draftsman and as a consequence he fails to make his meaning entirely clear on the drawing. If an object that is entirely without symmetry, i. e., one that is symmetrical about no plane, line or point, be called "right-hand," a corresponding "left" may be made, the "left" being a mirror image of the "right." But only one such "left" can be made, no matter what plane be taken as the mirror plane. On the other hand, if of such an object a "partial left" is to be made, i. e. if only part of its features are to be reversed by the mirror method, then the position of the mirror plane is of prime importance, since generally as many "partial" lefts" can be made as there may be mirror planes. This statement, of course, requires modification in case one or more points, lines or planes of symmetry exist. In the above letter our correspondent already made an unconscious selection of three mirror planes, namely, the central planes of length, breadth and height of the object. Reversal in height, as under (3) of the above letter, rarely or never occurs, but in the case given a real doubt exists between (1) and (2). In most drawings where an object is shown by several views, one of the views may be regarded as the principal one, for instance the front elevation; a note regarding right and left may then fairly be taken to refer to the object as it appears in the principal view, so that any interchange from right to left would be made from the right-hand side of this view to the left-hand side. The example of the column, where generally both elevations have equal prominence, is a case in which this guide fails. But even where it is clear how the reversal should be made, it is confusing to pick out one or two details of an unsymmetrical piece for reversal, and the time saved in the drafting room by the too free use of "right-and-left" notes may be more than made up by the time lost in the workshops.—Ed.)

Proposed Steel Dam, Irrigation Reclamation Service, U. S. Geological Survey.

Sir: With the approval and encouragement of Mr. F. H. Newell, Chief of the Hydrographic Bureau of the U. S. Geological Survey, I submit for publication a general plan of a type of steel dam which has been and is under consideration in that office in connection with the extensive construction of future storage reservoirs for irrigation.

In view of the public interest in the irrigation improvements by the general government a discussion concerning a very important feature of the same in a professional periodical ought to be pertinent, as all criticism is more desirable before than after any harm has been done. Readers of engineering papers will recollect that the general idea of the plan proposed is by no means a novel one, but has been more than once carried out with apparent satisfactory results, though in somewhat different shape and for smaller hydrostatic pressure.

It may be useful to remark that most all sites for high dams are selected in places which offer a resistant rock foundation. Water falls over the crest in most all cases during a comparatively short period of the year, only. As only pure water will pound down on the rock and repairs are easy, not much trouble is anticipated from wearing away the foot of the dam.

The construction proposed is self-explanatory. The only novel and important feature is the use of hardened steel for the compression members, such as the inclined columns of the bents and the polygon arch ribs. For these, high unit strains are adopted in computation, based on tests in small scale. It is proposed, however, to subject some test columns to test loads, amounting to the double of said unit strains, thus providing for the same safety factor as is used for ordinary structural steel when quiet load and repeated loading are conditions. Such columns should not show any permanent deformation after test. The column here proposed consists of a cylindrical steel tube of ordinary steel, a central core of hardened steel, and a concrete-filling between, direct stresses being resisted by the core alone.

From estimates regarding this type, which is applicable in most all cases, it appears that the object in view, of getting a reliable storage reservoir for the next 50 or probably 100 years, could be attained for about one-half of the expense required for a masonry dam. Approximate estimates for some other dams, of even double the height, show a similar proportion.

It would seem, at first thought, that where a stone-fill dam is made possible by diverting the overflow through separate spillways, or through tunnels, the result would be in favor of the stone dam. This will, however, prove erroneous, whenever a metal sheeting is required for water-tightness, as will happen in most all important cases.

As for the safety of masonry dams, as compared with steel dams, it will be acknowledged that of the former many have been built, and quite a number have failed, while of the latter few have been built and no failures have been recorded so far.

As to the same question for very high dams, any practical and responsible constructor in steel would consider the step similar to the step from a five to a twenty-story frame building.

In masonry dams another element or two come into the computation, which for lower dams are and may sometimes justly be neglected, it is, the shearing-stress which increases in geometrical proportion with the height

TABLE OF STRESSES AND SIZES FOR PROPOSED STEEL DAM.

	Cylindrical Plates. I. to II.	II. to III.	III to IV.	IV. to V.	V. to VI.	VI. to E.	Vertical.
Maximum pressure, lbs. per sq. ft.	6,500	5,700	4,900	4,100	3,300	2,500	1,900
Tension, lbs. per lin. ft. of width	97,500	85,500	71,500	61,500	49,500	37,500	51,300
Tension, lbs. per in.	8,120	7,120	5,960	5,120	4,120	3,120	4,270
Net area, sq. ins. (for 18,000 lbs.)	0.45	0.396	0.332	0.284	0.228	0.173	0.236
Thickness of plate	9/16-in.	½-in.	7/16-in.	5/16-in.	5/16-in.	¼-in.	5/16-in.
	Arched Ribs.						
Average pressure, lbs. per ft.	183,000	159,000	135,000	112,500	90,000	69,000	
Stress at center, lbs. per ft.	1,054,000	914,000	777,000	640,000	517,000	396,000	
Stress at ends, lbs. per ft.	2,108,000	1,828,000	1,554,000	1,250,000	1,034,000	792,000	
Maximum area (for 150,000 lbs), sq. ins.	14.1	12.4	10.4	8.6	6.8	5.3	
Maximum sizes, sq. ins.	3½×4¼=14.9	3½×3¾ = 13.4	3½×3 = 10.5	3×3=9	3×2½ = 7.5	3×2½ = 7.5	
Average area, sq ins.	10.4	8.4	7.3	6.0	4.8	3.7	
	Lower Chords.						
Maximum stress, lbs.	−100,000	−80,000	−60,000	−200,000	−700,000		
Net area (for 18,000 lbs.), sq. ins.	5.6	4.5	3.3	11.2	38.9		
Size, ins.	1 Pl. 12×½=6	1 Pl. 12×⅜=4.5	*18×¾	†18×¾	‡18×¾		
	Columns.						
	I.	II.	III.	IV.	V.	VI.	
Stresses from water pressure, lbs.	5,300,000	3,700,000	3,100,000	2,600,000	2,100,000	1,720,000	
Stresses from weight, lbs.	200,000	200,000	200,000	200,000	200,000	240,000	
Total stress, lbs.	5,500,000	3,900,000	3,300,000	2,800,000	2,300,000	1,960,000	
Net area (for 150,000 lbs), sq. ins.	36.7	26.0	22.0	18.7	15.4	13.1	
Size of rib, ins.	5×7½=37.5	5×5½ = 27.5	5×4½ = 22.5	4×4¾ = 19.0	4×4=16	4×3¼ = 13.0	
Stiffener	Concrete.	Steel.§	Steel.	Steel.	Steel.	Steel.	

*1 plate. †2 plates. ‡3 plates. §Steel cylinders 18 ins. diameter, ¼-in. plate.

of the dam, and also the absolute necessity of water-tightness at the up-stream face in order to prevent the buoyancy corresponding to the full base of the dam and maximum hydrostatic pressure. For such cases of great height, which usually occur at the most favorable reservoir sites, past experience is not available, and theory is decidedly in favor of steel construction as the safer and, of course, the cheaper.

It is clear, that the rules governing the construction of steel frames, in general, are much more precise than for masonry, where so much depends on uncontrollable circumstances, such as nature of material at hand, temperature and atmospheric influences. Unless metallic sheeting is used in high masonry dams they would not be entirely water-tight, and hence are subject to gradual decay, which will be very much accelerated, where exposed to freezing. Such dams, may in places, even when solidly built, not overreach the age of a well maintained steel dam.

Taking iron and steel structures on railroads as a parallel, it appears that long before the entire depreciation of the steel dam, in fact only after a few years, the saving with compound interest, as compared with masonry, would represent the price of an entirely new dam, suitable for the most recent improvements of the locality. It is safe to say that what has been experienced in transportation and other great industries will probably occur with respect to irrigation works; namely, that the age limit will reach far beyond the time when the development of the country makes new structures, improved with respect to location or capacity, either very desirable or unavoidable.

As for destruction through neglect, mischief and similar causes, it will be evident that the destruction of a small part of a stone dam would endanger at once nearly the whole of it, and the territory below; while in case of a metal dam the removal of a whole bent through violence or long neglect would simply make an opening in the dam; the remainder of the steel dam, however, would remain intact during and after the rapid but considerably checked discharge of the bursted reservoir.

Very respectfully, Chas. R. Steiner.

618 E St., S.E., Washington, D.C., April 25, 1903.

(A comparison of the costs of a steel and a masonry structure in which the weights of the steel are estimated on the basis that it is to carry a working load of 150,000 lbs. per sq. in. in compression, ought to be accepted with a very large degree of caution—if accepted at all. It may be true that steel dams will be more economical than masonry dams for the locations specified, but the steel work in such structures should certainly be designed on well-known and generally accepted principles. An important dam, particularly one built by the Government, is not the place to experiment on loading materials with greater burdens than the accumulated experience of the engineering profession has fixed upon as safe.—Ed.)

INSTRUCTIONS TO INSPECTORS OF CAST-IRON WATER PIPE, SPECIAL CASTINGS AND STOP VALVES, PHILADELPHIA.*

In accepting material under this contract inspectors are hereby directed to exact rigid compliance with all the requirements referring to the shape, size, thickness, eccentricity and soundness of all pipes, special castings and stop valves therein specified, and with the requirements of Paragraphs 11, 12 and 13, referring to the quality and tests of metal to be used in the construction of pipes, special castings and stop valves. No deviation whatever from these conditions will be permitted on the part of inspectors, and in cases where material has been rejected which, in the opinion of the contractor, might be used, the exact cause of rejection must be reported promptly to this office in order that it may be determined whether the rejected pieces can or cannot with safety be accepted for use in the work. No deviation whatever from the contract requirements will be permitted by the inspector, except upon written orders, signed by the Chief Engineer.

All pipes, special castings and stop valves must be consecutively numbered, whether the prices be accepted or rejected; the test bars must also be numbered and the series of numbers for each be connected with the numbers of the pipes, special castings or castings for stop valves manufactured from the same heat. Thus, test bars Nos. 1, 2, 3, 4, 5 and 6 for 60-in. pipes correspond with pipes Nos. 1 to 6 inclusive, or to whatever number of pipes may be made from that heat, and with such special castings stated by numbers and symbols run from the same metal as is represented by test bars Nos. 1, 2 and 3, etc., and so on throughout the inspection for this contract, and for other than 60-in. pipe there will be required from each heat two (2) test bars for cross breaking loads and two (2) tensile test specimens for breaking in the testing machine. These bars in the same manner must be correctly related to the pipe and special castings made from that heat.

Paragraph 12, "Test Bars." Not less than six (6) test bars for cross breaking load shall be made from every heat for 60-in. pipe and special castings, and two (2) test bars from every heat for pipe and special castings other than 60-in. These test bars must be taken at different times during the heat in order to show the quality of the metal at the beginning, during and at the end of the heat, as represented by the material drawn into the ladles and poured into the flasks. Thus, if the heat for 60-in. pipe requires three hours to pour off, a test bar should be run from the first ladle and one every half-hour thereafter during the heat until the proper number of bars are obtained.

If the heat consumes six hours, a cross breaking test bar must be poured each hour, and a tensile test bar once each two hours of such heat, or in this order whatever the length of time to pour off the heat for each particular day.

The test bars in each instance must be taken from the same ladle which carries the molten iron from the cupola to the flasks.

If the special castings are not poured from the same cupola as that supplying material for pipe, then the test bars must be duplicated from the cupola supplying the material for special castings; that is to say, if the special castings are for connection with 60-in. pipe, six (6) test bars in addition to the six (6) test bars herein mentioned must be taken from the cupola for special castings.

Where one cupola supplies the material at the same time for both pipe and special castings, six (6) test bars taken as described in Paragraph 12, will be held to apply to both the pipe and special castings.

The inspector will be required to see that the bars for cross breaking tests, and the three additional bars cast separately and milled for tensile tests, Paragraph 12, are boxed up and forwarded to this office regularly each day by express.

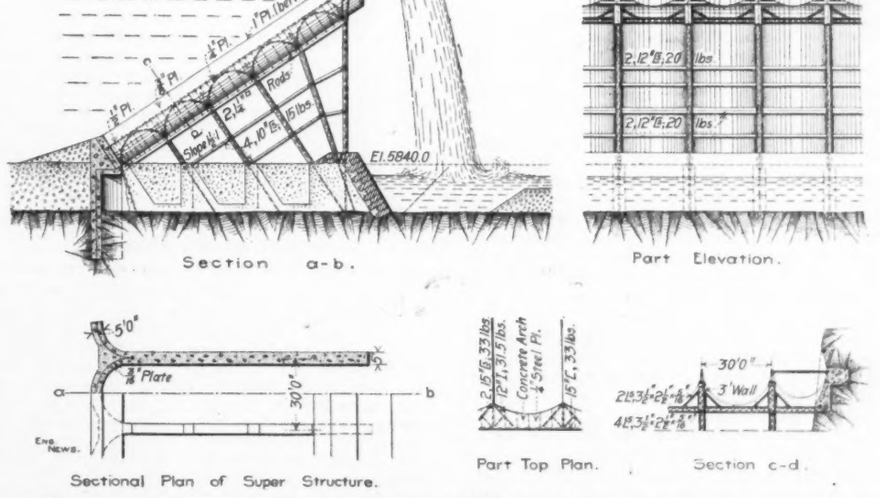
The duplicate set of cross breaking bars and tensile test bars which the foundry will make, will be broken and deflections determined on the testing machine at the foundry. The inspector will be required to be present when these tests are made and certify to the results, and any casting made from metal falling below the requirements of the contract, even though otherwise satisfactory, shall be rejected.

Referring to Paragraph 35, "Hydrostatic Test," inspectors will note that each pipe must be subjected to an internal hydrostatic pressure of 300 lbs. to the square inch, for an interval of time not less than ten minutes, or longer if in your judgment it is necessary to prove that such pipe is tight and not sweating through the pores of the metal. With reference to the 300 lbs. hydrostatic test this must absolutely be made with every piece of pipe and special casting, excepting curves and breeches pipes, the inspection of which must be made to show absolute compliance with the other requirements of the contract, because these specials cannot conveniently be subjected to the hydrostatic pressure test.

In the case of rejection of curves or breeches pipes, because of their non-compliance with the requirements for form, uniformity of thickness of barrel, etc., if the contractor will arrange to subject such castings to the hydrostatic test required by Paragraph 35, and they are found to meet such test satisfactorily, this fact must be reported to the office for such further action as the Chief Engineer may take with reference to such special castings.

Note the preparation of the coating bath and see that the same is kept at the proper consistency and at the required temperature, also that the castings before immersion are carefully cleaned and heated as required. See that the castings are kept in the bath long enough to become thoroughly coated inside and outside. The inspector shall see that in heating pipes in the oven before they are put into the bath of pitch and oil they are not brought to

*On Contract No. 28, Lardner's Point Distribution System, Improvement, Extension and Filtration of the Water Supply. John W. Hill, M. Am. Soc. C. E., Chief Engineer, Bureau of Filtration, Philadelphia.



DETAILS OF PROPOSED STEEL DAM, IRRIGATION RECLAMATION SERVICE, U. S. GEOLOGICAL SURVEY.

a temperature high enough to burn the material in the coating tank. The oven for heating pipe and special castings must be fired with coke or anthracite coal.

Paragraph 20, page 37, "Defective Bead Ends." This clause must be construed as applying only to pipe 48 ins. and less in diameter. No provision is made for cut 60-in. pipe, and if occasion should arise where it might be advisable to cut such pipe, specific instructions with reference to banding will be furnished from this office.

If the foundry where the inspector is stationed should not be provided with calipers having a reach of 5 ft., with a self-reading scale whereby the thickness of the pipe at any point in its length or diameter can be quickly read, he shall notify this office and such calipers will be furnished, to be returned to this office when he has completed his work.

In calipering pipe for thickness of metal it must be taken near the bell and near the spigot, and at two points equidistant between the bell and spigot, and at four points, 90° apart around the circumference of the pipe, and if upon this measurement there is reason to believe that the thickest and thinnest sections of the pipe have not been shown, then it will be necessary to continue until the extreme difference of thickness has been stated.

In calipering pipe for diameter of bore, this should be taken at four points and stated as shown in the Inspector's Note Book prepared by the city for the purpose.

Upon inspection of special castings for all requirements with reference to thickness of flanges, barrels, dimensions, depths and condition of bells, sizes and condition of beads, facings of flanges, diameter of bolt circle, number and size of bolts and other ordinary conditions, a careful examination must be made for spongy spots where the flange joins the reinforcement of the casting, and the bell joins the barrel of pipe or special casting. This can best be done with a blunt punch and hammer, and wherever such parts are suspected the punch and hammer must be applied until the inspector is satisfied that the metal is solid.

Spongy spots in the iron where the flange joins the reinforcement of the casting or the bell joins the barrel of the pipe or special casting, will be considered sufficient cause for rejection.

Where the flanges or flange castings do not face up smooth and free from blow holes and sand holes, such castings will be rejected, and the facts reported to the Chief Engineer. In reporting castings so rejected the inspector should make a sketch of the flange and indicate on the same, the location, number and size of the spots which do not face out in the lathe or in the boring machine. The back of all flanges shall be smooth, parallel to the faced surface, and furnish a proper seat for nuts and bolt heads.

Submit daily reports to this office of all pipe, special castings and stop valves made under the contract either accepted or rejected, giving the data called for in the blanks furnished.

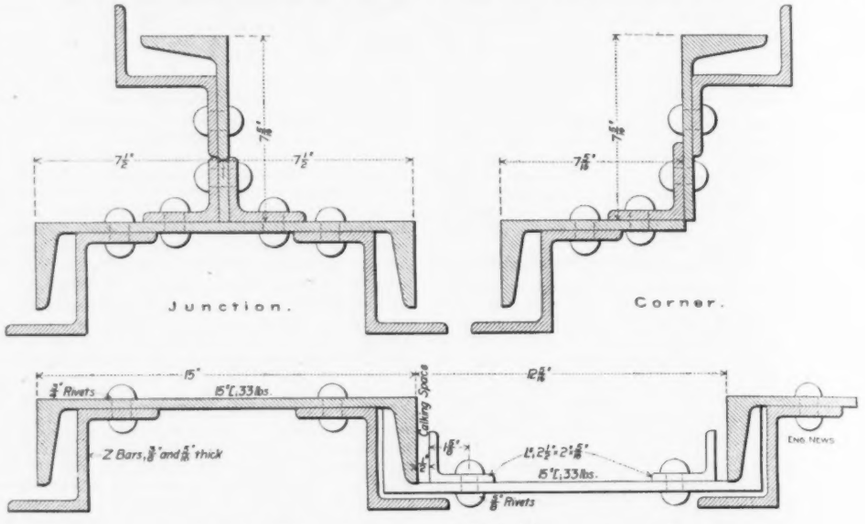
If subsequent examination of castings, after arrival upon the work at Philadelphia, should indicate neglect upon the part of the inspector at the foundry, it will be deemed *sufficient cause for his removal.*

STEEL SHEET PILING.

In many foundation works, particularly in quicksand and wet ground, the ordinary timber sheet piling cannot be used to good advantage, and on works of this kind the use of steel sheeting is now being introduced. The accompanying cut represents a style of steel sheet piling which has been used for the sheeting of foundations, mine shafts, and also for cofferdams, locks, etc.

The cut clearly shows the construction of the sheeting, and also two arrangements for corner construction. The piles consist of ordinary 15-in., 33-lb. rolled channels (with metal ⅜-in. thick), each alternate channel having riveted to it two steel Z-bars, forming grooves to receive the flanges of the adjacent channels. These bars are 4 × 3 × 3 ins., ⅜-in. thick. In this way the piles are so firmly interlocked that a line of sheeting will resist heavy pressure without the aid of shoring or bracing. In water, the joints are soon caked by the accumulation of mud, sand or dirt, but if the water should be very clear, a little sawdust, paper pulp, manure, etc., may be thrown in near a leak, which will soon be sealed. In the Mississippi River cofferdam at St. Louis, noted below, the alternate piles had two angle irons 5-16 × 2½ × 2 ins. riveted on (as shown in the cut) to form calking grooves, in which strips of wood might be fitted. These, however, have been found unnecessary, and have been omitted on part of the work.

This steel sheeting has been used for sinking mine shafts through quicksand, and for the foundations of the Union Traction Building at Cincinnati, and the new Railway Exchange Building at Chicago. The latter will be a 17-story "skyscraper" office building, at Jackson Boulevard and Michigan Ave., and the site will be excavated to a depth of nearly 30 ft. As there is a bed of quicksand underlying the site, it was decided to completely surround it with a steel sheeting, driven to a depth of 30 ft., which will resist the pressure from the outside and so prevent flow or caving which might injuriously affect adjacent buildings. This work is now in progress. An ordinary pile driver with a 2,000-lb. hammer is used, the head of the pile being fitted with an iron cap having a wooden cushion and a wooden striking block. The sheeting has been used also to form the cofferdam for the new power house of the Union Electric Light & Power Co., at St. Louis (Eng. News, Nov. 6 and Dec. 18, 1902). The location is on the bank of the Mississippi River, and a cofferdam, 40 × 360 ft., was built of the steel piles, 50 ft. long, braced only by cross walls dividing it into panels or sections, 40 × 60 ft.



A NEW TYPE OF INTERLOCKING STEEL SHEET-PILING.
Interlocking Channel Bar Co., Chicago, Manufacturers.

The piles are rolled of any length up to 60 ft., and can be spliced for longer lengths. In many cases it can be pulled up and used over again, and discarded material will have a high scrap value. The pilinig is the invention of Mr. L. P. Friestedt, of the Interlocking Channel Bar Co., Tribune Building, Chicago, and is manufactured by that company.

SOME PRACTICAL SUGGESTIONS CONCERNING THE GENESIS OF ORE DEPOSITS.

By Max Boehmer,† M. Am. Inst. M. E.

During the last few years the "Transactions" of the Institute have been especially rich in discussions pertaining to the genesis of ore deposits. Starting with the masterly treatise of Professor Posepny, which successfully demolished Sandberger's theory of "lateral secretion from the rocks in the immediate vicinity of the veins," we have since had very thorough and able papers from the hands of Le Conte, Vogt, Kemp, Emmons, Lindgren, Van Hise, Weed, Spurr, Rickard and others. It would seem that the combined efforts of so many able men should have solved the problem satisfactorily by this time. Indeed, Professor Le Conte, quite a while ago, expressed his definite opinion that the problem had been solved, so far as the geologist was concerned. However this may be, it seems certain that those whose particular business it is to examine and estimate the value of mines, and whose special work takes them underground in all the mining districts of the United States and other countries, are not wholly satisfied, but are still in doubt on many points relating to the origin of the ores in the various mines they are called upon to examine.

The subject is of the highest economic importance. A comprehensive theory, once fully established and understood, would be of immense and immediate practical value to all engaged in the mining industry. It would be of great value in formulating plans for the proper development of a mine and throw light upon the dark and undeveloped portions.

*A paper to be read at the British Columbia meeting of the American Institute of Mining Engineers.

†Mining Engineer, 42 Jacobsen Building, Denver, Colo.

THE ERUPTIVE ROCKS.

The first and most lasting impression made upon the mind of him who examines a mine or a mining district consists in the observation that in each and every case there is an intimate association of the ores with the eruptive rocks in the district. The mines in the Mississippi Valley seem to be the only exception to this rule. It may be possible that further development or closer examination will still discover these, as was the case in Butte, Montana. In that district the porphyry dikes had not been especially noted, and were not generally known to exist until about ten years ago, when the frequent lawsuits necessitated a closer inspection of the ground. This intimate association of the eruptive rocks with the ores, true the world over, convinces the practical mind that there must be a genetic relation between the two. Upon a further examination of the district, it is frequently found that the ore-bearing veins are confined to certain areas, although the eruptive rocks continue for miles beyond. This, again, proves that other factors, not directly connected with the eruptive rocks, have been at work, and that such factors are local in their origin and effect because they are limited to certain portions of any given district. This fact, it would seem, precludes any attempt to explain the origin of ores which does not specifically account for the localizaton of the deposit.

The most obvious conclusions to be drawn from this intimate association of metalliferous veins and eruptive rocks is, that the source which furnished the material for the rocks is likewise the source of the waters which deposited the ores in the fissures. I take it as conclusively established that by far the larger number of ore deposits are the work of underground water. Whether it is possible and probable that the source indicated is the true one must be demonstrated in a discussion of the circulation of underground waters.

THE SEA OF UNDERGROUND WATER.

All authorities agree that, as the earth cools, cycle after cycle an increasing amount of water is absorbed and added to the sea of underground water. The water has worked its way downward ever since the cooling crust of the earth permitted its accumulation at the surface. And this process will continue until the earth cools to the center and finally absorbs all the waters of the globe. The lower boundary or bottom of this sea of water is limited and determined by the heat conditions of the interior. How far this limit reaches, it may be impossible to determine; but it is certain that it reaches the region of metamorphism, because this process of change of the sedimentary rocks cannot be carried on without the presence of water. Nor is this water a local occurrence brought about by the opening of some deep-reaching fissures or by the subsidence of blocks of sedimentary rocks including masses of water. This superheated belt of water, near the bottom of the underground sea, must be universal in its scope, because the underlying granite is universal. The granite represents the ultimate stage of metamorphism, and cannot crystallize except out of magma in hydro-thermal fusion.

If this is correct, we have passed the zone of rock flowage, which, according to Professor Van Hise, is the downward limit of underground water. Perhaps the bottom of the zone of rock flowage is identical with the belt of hydro-thermal fusion.

It is a well-known fact, and has been repeatedly demonstrated by experiment, that rocks which require a temperature of 3,000° F. for ordinary, dry fusion, can be made to assume a pasty or liquid form at a temperature of 500°, in the presence of sufficient water under pressure.

These conditions must exist at some depth at all points, if the existence of an underground sea of water, ever working its way downward, is admitted as universal. The extent in depth of this belt of hydro-thermal fusion it is probably impossible to estimate. But its waters, if not in active circulation, are ever moving and hard at work, leaching, extracting and keeping in solution the most

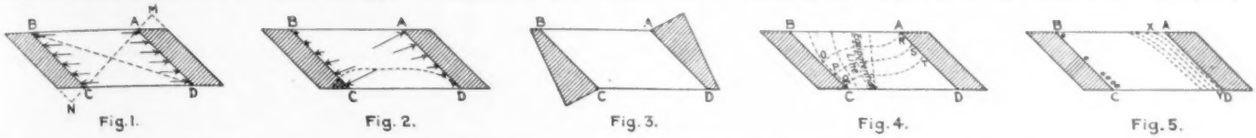


Fig. 1. Fig. 2. Fig. 3. Fig. 4. Fig. 5.

soluble elements present. This region must be the seat of continual activity. The hydration and dehydration of minerals, the crystallizing and dissolving and re-crystallizing must be ever going on, until we have a steady, never-failing reservoir of superheated waters under great pressure and charged to saturation with the metals and the minerals present.

Nor can this reservoir be tapped from above and its burden of metals in solution be brought toward the surface without a catastrophe. The rending of a crevice or a fissure in the crust above sufficiently deep to reach this belt, and sufficiently open to permit operation of gravitative stress upward, alone, can start the circulation of these waters and bring them toward the surface.

It is correct, no doubt, theoretically, that the waters of a river running into a lake at one end, and out at the other, affect and move the entire body of water, however deep. So it is true that the surface waters, daily pouring down to join the underground sea, affect the entire sea to some extent.

But in the deeper region, where the rocks are tight and the water works its way slowly and gradually downward, friction most certainly has obliterd all effects, or nearly all, of hydrostatic head and stress by difference of temperature. The sea in its lower portions, therefore, must be regarded as stagnant. And a stagnant mass of water, although saturating the rocks throughout, can do but little leaching until the pressure and the heat reach a degree sufficiently great to dissolve and fuse the rocks. And this is the beginning of the belt of hydro-thermal fusion, and here we find material sufficient to fill the veins.

The mining engineer in active practice will find it difficult to accept the theory of Professor Van Hise, which makes the deposition of ores nothing more than an accidental and specially emphasized phase of the work of the underground circulation of meteoric waters. Such a theory would make a metalliferous vein out of all crevices and fissures at all points and at any depth.

It fully accounts for the existence of mineral springs and hot springs, with a possible and occasional admixture of the metals in their waters; but it fails to explain the localization of the deposits, depreciates the importance of the eruptive rocks, and does not convince us that the waters feeding the springs of the earth are the same which have deposited the millions of tons of ore in the great mining districts.

That the waters in the vadose region above the groundwater level should be able to collect any respectable quantity of metal seems improbable, in spite of their greater activity in the more open rocks near the surface. These waters, reinforced by every rain and melting snow, do not search the rocks nor leach much value from them, because they naturally choose the more open spaces, enlarge them, and create their own channels, in which they remain permanently. When these waters reach the groundwater level, they naturally spread out upon its surface, run off laterally (there being less impediment to their course above this level), and reach daylight again at a lower elevation.

That an underground sea of water, continuous and saturating the rocks throughout, really does exist, seems a corollary of the fact that the water, once held entirely at the earth's surface and above it, has gradually worked its way into the cooling earth; the only argument against it consists in the fact that a number of shafts have been sunk in wet ground for many feet, and at greater depth encountered a region free from water. Cannot this be explained by the probable existence of an impervious stratum at the point where the water ceased? I take it that such occurrence simply illustrates the very irregular contour of the groundwater surface. These shafts, if sunk still deeper, must encounter water again, if the underground sea of water does exist.

If, then, the existence of an extensive belt of hydro-thermal fusion be admitted, and if it is true that this belt is constantly supplied with water by a permanent underground sea, it will not be difficult to explain the mineralization of our veins and their localization. An extensive movement in the crust creates a profound and complicated set of fissures at certain points. These fissures reach the belt of fused rock. The blocks of solid rock above sink into the fused mass, and squeeze it into the fissures toward the surface. This makes the dikes and sheets of eruptive rock as we find them near the veins. Simultaneously or later, other fissures, not sufficiently open or not in proper position to admit the fused mass, start up the circulation of the waters and begin the making of a vein.

I have attempted to show that the waters in the zone of open fractice in the upper region do not search or leach the masses of rock, but that they flow through them in permanent and open channels; that the waters in the middle and lower zones of the underground sea are stagnant and not sufficiently effective; and that we must look still deeper for the source that could supply the immense masses of ore fcund in the veins.

The invariable existence and evident genetic relation of the eruptive rocks with our ore deposits suggest the source. Is it the true one? I refer the matter to geological specialists for further consideration.

THE STRESSES ON SKEW ARCHES.*

By W. C. Kernot,† M. Am. Soc. C. E.

Skew arches are of figures derived from those of symmetrical arches by distortion in a horizontal plane. The elevation of the face of a skew arch, and every vertical section parallel to its face, being similar to the corresponding elevation and vertical section of a symmetrical arch, the forces which act in a vertical layer or rib of a skew arch with its abutments, are the same with those which act in an equally thick vertical layer of a symmetrical arch with its abutments, of the same dimensions and figure, and similarly and equally loaded.

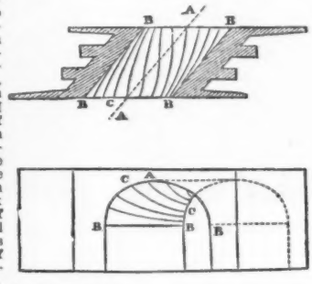


Fig. 108 represents a plan of a skew arch, with counterforted abutments. The angle of skew, or obliquity, is the angle which the axis of the archway, A A, makes with a perpendicular to the face of the arch, B C A B. The span of the archway, "on the square," as it is called (that is, the perpendicular distance between the abutments), is less than the span on the skew, or parallel to the face of the arch, in the ratio of the cosine of the obliquity to unity. It is the span on the skew which is equal to that of the corresponding symmetrical arch.

The above statement, taken from Rankine's "Applied Mechanics," p. 261, and copied substantially in Colonel Wray's "Instruction in Construction," p. 444,‡ represents what has hitherto been the accepted view of the engineering profession. In accordance with it large numbers of skew arches in masonry, brickwork, concrete, or Monier, have been built in England and other European countries, and a small number in Australia. As our railways increase in number and importance, and the necessity of replacing short-lived timber structures by more permanent works, and substituting for level crossings over or under bridges of substantial character, this number will steadily increase. Hence it is of practical and local importance to discuss the reliability of the hitherto accepted view.

Rankine's theory is illustrated graphically in Fig. 1, where the arrows show the supposed direction of the horizontal resolved part of the thrust, and their equality in length indicates that the thrust is equal on each unit of length of the abutment. That this is Rankine's belief is proved by the counterforts in his Fig. 108, above quoted, being of equal length at each side of the arch and being in a direction parallel to its face.

On the 14th May last, a Monier arch of considerable size, and built at an extreme skew, collapsed at Bendigo, unfortunately, with loss of life. The failure was sudden and unexpected, unlike the recorded mode of failure of Monier arches that have been tested to destruction in Europe and elsewhere, in which cases numerous and conspicuous signs of distress were visible long before the final collapse. The contractor, who was no other than our worthy President, at once retained the services of the writer of this paper, and in describing to him the disaster expressed doubts as to the correctness of the received theory of skew arches. These doubts appeared reasonable, and led the writer to examine the matter closely. Assuming the abutments to be immoveable, which must be very nearly correct, as they are small in height, massive in section and founded on solid rock, and that the arch was perfectly and uniformly elastic, so that the stress in any given direction would be proportional to the change of dimensions, the following calculation was made. The arch was supposed to have been pressed down to a given small extent by its own weight, and the superincumbent load, and the consequent reduction in length of lines traced on its extrados in the positions A B and A C were computed, the result being that the percentage of shortening in the direction A C was found to be almost exactly double that in the direction A B or in any line parallel to A B. Consequeutly, it followed that the heaviest stress in the arch was diagonally across from A to C, that the stress in the direction A B was only half as great, while that in the direction B D was found by an extension of the same calculation to be excessively small. In fact the distribution of thrust along the faces of the abutments instead of being as in Fig. 1, must be something like Fig. 2, the magnitude of the thrust at or near the acute angle of each abutment being greatly increased and its direction altered in an unfavorable manner, while at the obtuse angles the thrust would be very small indeed. Hence the abutments should have had the form shown in Fig. 3, being strengthened when the heavy thrust occurred, and for economy reduced at the other end.

By the time these conclusions had been arrived at, the debris having been removed, the writer had an opportunity of examining the fallen portion of the arch and the abutments contiguous, and found that the acute angle C had been absolutely pulverized though of good strong concrete, thus bearing witness to the great local intensification of stress. The heavily shaded area in Fig. 2 shows the extent of destruction of the abutment, and the dotted line extending from it the boundry dividing the portion of the arch which fell from that which remained standing. The strength of the Monier arch came out most clearly, for where it was provided with a sufficient abutment it had stood almost uninjured, though loaded with a steam roller at mid span and subjected to an enormous downward drag from the falling portion, transmitted through the grid of steel rods which forms the specialty of the Monier system.

In view of the preceding, there seems to be no reasonable doubt but that the accepted method of designing the abutments of skew arches was most seriously in error, and that the immunity from disaster in previous cases was due either, first, to the angle of skew being in most cases very moderate compared with that adopted at Bendigo, or, second, to the fact that the structures had not been subjected to such a specially severe test as the Bendigo council has insisted upon, and which, I may add, was a long way in excess of any test to my knowledge previously applied to a public road bridge, or, third, to the usual employment of a very large factor of safety. An excessive factor of safety, it has been well remarked, covers a multitude of sins in designing, but is neither creditable to the designer or economical as regards the client's money.

It appeared in the next place that a conclusion, so important and far reaching as the above, should be checked and verified in every possible way, and further, that definite rules or formulæ giving the magnitude and direction of the thrust at various points along the abutments, were very desirable as a guide to designers. The writer therefore placed himself in communication with the leading experts in elasticity known to him, but found them unable to supply the requisite formulæ. The mathematical theory of elasticity, though long a subject of study and possessing a considerable literature, appears not yet to be sufficiently developed for the purpose. Mr. Love, the demonstrator of physics at the University, and whose brother, Professor Love, of Oxford, is the leading British authority on elasticity, very kindly gave considerable attention to the matter, and after failing to indicate any direct mathematical solution, made a curious and ingenious suggestion, namely, that as there is a very striking analogy between the laws regulating the distribution of stress in an elastic solid and those regulating the flow of electricity in a conductor, while electrical experiments are much easier to conduct and capable of giving much more minutely precise results than measurements of infinitesimal elastic deformations, a metallic model of the bridge should be made, and a current of electricty being passed through it, its equipotential lines should be determined by well-known experimental methods, and that a series of lines drawn at right angles to these would give the direction of the stress, and by their convergence or divergence indicate where the stress became intense or the reverse. The experiment was actually carried out at the writer's request by Mr. Wilfrid Kernot, B. C. E., Lecturer on Electrical Engineering at the Working Men's College, who possessed special facilities for such work,

*A paper read before the Victorian Institute of Engineers.

†Professor of Engineering, University of Melbourne, Melbourne, Australia.

‡See also Encyclopædia Britannica, Vol. II., p. 330.

and the result is shown in Fig. 4, where it will be noted how greatly the current density, and by analogy, stress is intensified in the vicinity of the acute angles, A and C. The actual numerical result was that in a bridge of the proportions of that at Bendigo, three-fourths of the whole thrust was resisted by less than one-half of the length of the abutment, one-half of the total thrust by one-fifth of that length, and one-fourth of the total thrust by less than one-thirtieth of that length, and that the weakest and least effectively backed-up portion. These results are indicated by the position of the points O, P, Q, R, S, T. One-fourth of the electric current passed between A and R or Q and C, one-half between A and S or P and C, and three-fourths between A and T or O and C. The model experimented upon consisted of two massive copper abutments, connected by a thin German silver band to represent the arch.

The writer's own experimenting was of a different sort. He endeavored to construct and test an india rubber model having parallel lines or circles of known diameter drawn up it, the deformation of which would indicate the direction and magnitude of the stress. This model gave unmistakable indications of great intensification of stress in the vicinity of the points A and C, but was troublesome to manage. Taking advantage, therefore, of the well-known fact that an arch and a suspension chain have identical distribution of stress, the compression in one being represented by the tension in the other, an inverted model was made of thin sheet india rubber, which gave very definite and consistent results. These are shown in Fig. 5. The lines A D and X Y were originally parallel, but when the arch was loaded A X increased enormously, showing great intensification of stress, while Y D remained nearly unaltered. The stress then was very small at D, increasing gradually for about three-fourths of the length D A, and finally increased with great rapidity as A was approached. The same peculiarity is shown by the small circles drawn near the line B C. Most of these remained almost unchanged, but those near the point C were greatly distorted, showing a very heavy stress approximately in the direction A C, which is quite contrary to the received theory. Other experiments have been tried with models in soap, cement, mortar and plaster of paris, but owing to various practical difficulties in carrying out the tests, the results, though on the whole confirmatory, have not been so consistent and satisfactory as is desirable. If other engagements permit, these tests will be repeated with better arrangements.

Corroborative evidence as to the truth of the views herein set forth is to be found from the behavior of skew beams. Let A B C D in Fig. 1 now represent a flat plate of any uniform material, supported at the edges A D and B C. By reasoning similar to that applied by Rankine and others to the skew arch, it would be anticipated that the downward pressure would be equally distributed along A D and B C. The simple experiment of attempting to lift the corners, A B, C D, in succession off their supports, however, shows that the pressure at A and C is enormously greater than at B and D. This has been verified with plates of thick india rubber, of pasteboard and of metal, with the most uniform and striking results.

The conclusion, then, is that the views hitherto held as to the distribution of stress in skew arches are most seriously and dangerously in error, and that an elaborate and costly series of experiments on a fairly large scale is urgently needed in order to establish reliable rules for the designing of such structures. Until such experiments are made, the following provisional rules are submitted, as representing the results of the small experiments at present available and as constituting at any rate a distinct improvement on the old unscientific system of the text books.

In conclusion, I must express my thanks to Mr. Love and Mr. Wilfrid Kernot for valuable assistance, and my sympathy with Messrs. Monash and Anderson, who unfortunately are responsible for the construction of the bridge that fell.

Provisional rules for proportioning the arches, abutments, and piers of skew bridges in brick, stone, concrete and Monier:

Angle of Skew.—90° signifying a square bridge.

Above 80°.—Design as at present.

80° to 70°.—The acute angle of each abutment and pier to be replaced by a right angle. See lines A M, C N in Fig. 1.

70° to 60°.—Increase the thickness of the arch by one-fourth at the points A and C. Such increased thickness to diminish in all directions until it vanishes at a distance equal to one-fourth of the skew span. Acute angles of piers and abutments to be replaced by right angles, and the thickness increased one-fourth at A and C, such increased thickness to diminish in the same way as that of the arch.

60° to 50°.—Same treatment as the last, except that the increased thickness of arches, piers, and abutments be one-third.

50° to 40°.—Same treatment as the last, except that the increased thickness in each case be one-half.

FIG. 1. VIEW OF REINFORCED CONCRETE ARCH BRIDGE, FOREST PARK, ST. LOUIS, MO.

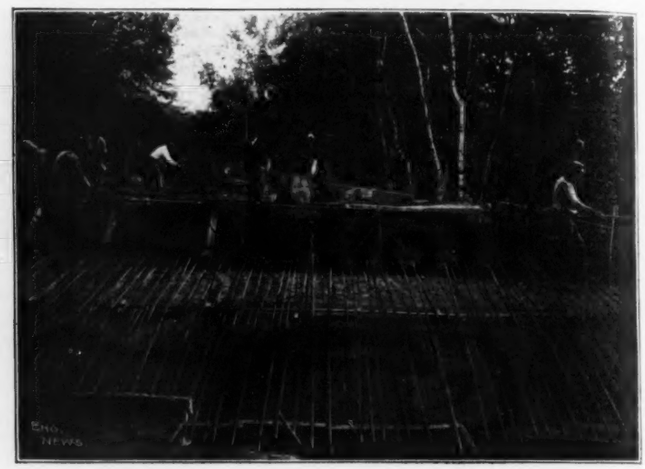


FIG. 5. VIEW OF FOREST PARK BRIDGE, SHOWING PLACING OF REINFORCEMENT.

Richard S. Phillips, St. Louis, Mo., Engineer.

REINFORCED CONCRETE BRIDGE OVER RIVER DES PERES, FOREST PARK, ST. LOUIS, MO.

We illustrate in the accompanying cuts the general details of a concrete arch bridge reinforced by corrugated square bars. This is one of the first occasions in which this form of reinforcement has been employed in arch bridge construction and, while the bridge described is of moderate dimensions, the fact seems worthy of being placed on record particularly as the special corrugated bar reinforcement is being pushed commercially with much energy and is certain to be brought to the attention of engineers who are designing reinforced concrete work.

When the city of St. Louis, Mo., by ordinance, granted the use of the western half of Forest Park to the Louisiana Purchase Exposition, the River Des Peres wound its way through a tortuous channel 8,800 ft. long within the limits of the Exposition site, entering the park on the north side. This section of the park, known as the "Wilderness," comprised an area of 1,500 × 2,000 ft., which was covered with a jungle of briers, buck bushes, grapevines and thick underbrush, and which with the numerous bends in the river gave but a sluggish flow to its waters. The layout plan of the exposition buildings, which was adopted by the Commission of Architects, necessitated changing the channel so as to confine it within the limits of the streets which shortened its course to 4,650 ft. As the new channel was lined on bottom and sides with surfaced lumber the velocity of flow was too great for the channel below, and to remedy this trouble four horseshoe bends in the eastern portion of the park were taken out by cutting new channels directly across the bends. This channel diversion made necessary a new bridge over the river a short distance east of the exposition site, and a reinforced concrete arch, with terra cotta posts and an ornamental iron railing was adopted. A general view of this bridge when nearly completed is given by Fig. 1.

The bridge has a span of 45 ft. and is 45 ft. wide. The flow area is 585 sq. ft. Fig. 2 is a longitudinal section of the bridge and Fig. 3 is a transverse section at the crown, which shows also the roadway and sidewalk construction. The main dimensions of the different parts of the bridge are shown by the drawings. It will be noticed that the spandrel walls and arch ring faces are molded to resemble ashlar masonry and that there is a molded cornice.

The concrete used for the arch ring and spandrel walls was composed of 1 part Portland cement, 2 parts sand and 4 parts of limestone broken to 1½-in. size. For the abutments a 1-3-6 concrete was employed. The reinforcement as already stated consisted of corrugated steel bars placed in pairs at intervals across the bridge. One bar of each pair follows the intradosal curve of the arch ring and the other, located vertically above, follows the extradosal curve. The sketch, Fig. 4, shows a short section of one of the bars. This form of reinforcing bar is made by the St. Louis Expanded Metal Fireproofing Co., of St. Louis, Mo., Mr. A. L. Johnson, M. Am. Soc. C. E., engineer. The following explanation of the design and construction of the bar is given by the company:

By numerous practical examples as well as by laboratory tests, it has been determined that it is very easy to break the adhesion between the concrete and the surface

Fig. 4. Sketch of Corrugated Bar Reinforcement for Forest Park Bridge.

of the embedded metal, and it is therefore not safe to use plain bars, or any form of bar depending upon this adhesion for its efficiency. The bar should be provided with some form of ribbing device, the sides of which ribs should be nearly at right angles to the axis of the bar, varying therefrom by an angle not exceeding the angle of friction between the materials used. Our corrugated bar is designed on this principle, and the practical results and tests that have been made by others, as well as by ourselves, have proved the correctness of the theory. Theory and practice do not always agree, but they do in this case. This bar is rolled hot, like any other shape, from special material, and has double the amount of work put on it that is given ordinary structural steel. This results in a very high elastic limit, which is desirable in steel-concrete construction, the load producing this stress in the steel being the ultimate load of the combination in all cases.

The corrugated bars were spaced as shown by Figs. 2 and 3; those at the intrados being laid in two lengths lapping about 6 ft. at the crown, and those at the extrados in three lengths with 6-ft.

laps at the haunches. The bars were all ⅝-in. square.

In constructing the bridge the abutment piers were first built in pits sunk to solid foundation, about 5 ft. below the flow line, and lined with sheet piling. Arch-ring forms were then built, the arched portion being supported on a well-braced series of posts resting on sills. To give the cut-stone effect, V-shaped strips were nailed to the inside of the forms. These strips and the form for the cornice were gotten out at a planing mill. In placing the concrete, a mortar facing of 1 part Portland cement and 2 parts sand mortar was placed by drawing back the concrete from the form and filling in the space, taking care to bring the facing and backing into a good bond and to keep the broken stone at least 1½ ins. from the face. The face obtained by this mode of procedure was generally neat and clean, there being only a few places where honeycombed spots showed, where slight openings in the form had allowed the mortar to escape. Some trouble was had in placing the bars. The rods being slender as compared with their length, it was found impossible to hold them in proper position except by a system of wood blocking. This blocking served its purpose in a somewhat unsatisfactory manner, since it had to be removed as the concreting proceeded.

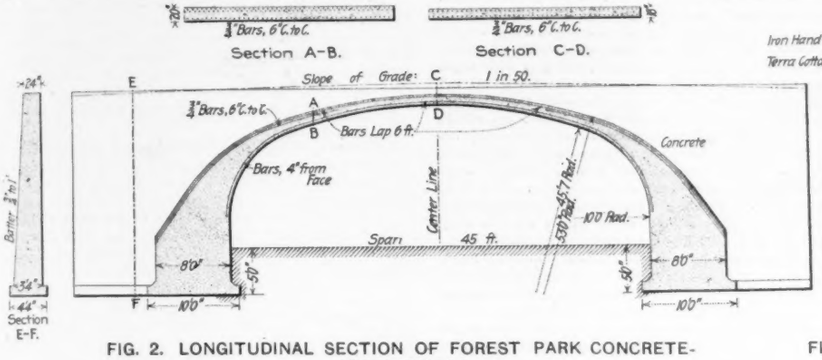


FIG. 2. LONGITUDINAL SECTION OF FOREST PARK CONCRETE-STEEL BRIDGE.

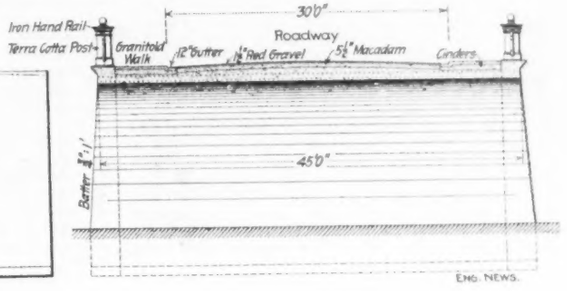


FIG. 3. TRANSVERSE SECTION OF FOREST PARK BRIDGE.

It is thought by the engineers that better results would be got by using sheet-steel spacers to hold the bars and by leaving these spacers in the structure. The close spacing of the bars and the necessity of getting the concrete firmly tamped around them made the concreting a slow and tedious operation. The centers and forms were removed about nine days after placing the last concrete. The view, Fig. 1, shows the centers lowered and in process of being removed. Fig. 5 is a view of the top of the center showing work in progress placing the reinforcing bars.

The bridge was finished the latter part of October, 1902, and has been in use since. It cost, including about $2,000 spent in grading and riprapping, $12,600. The bridge was built by the Louisiana Purchase Exposition under the direction of Mr. Richard H. Phillips, Chief Engineer, Department of Civil Engineering, Division of Works. We are indebted to Mr. Phillips for the information from which this description has been prepared.

MALLEABLE CAST IRON.*

By Dr. Richard Moldenke.†

Whatever may be the scientific definition of a malleable casting, for commercial purposes it is one made of iron of special composition and rendered malleable by subsequent annealing. The composition of the hard casting lies between well defined limits, and it is affected by so many conditions that the successful production of this class of work is one of the most difficult branches of the iron industry.

While nominally the composition of a good malleable casting is but little different than that of a car wheel or a roll, yet the fact that it can be twisted, bent and hammered out hot or cold, and has double the tensile strength of these other products, shows that the constitutions of the castings are quite different. This difference in the constitution may be traced to the condition of the carbon in each. In the ordinary gray casting we may have some 3 to 3½% graphite. In the malleable casting we have the same amount, weighed as graphite in the analysis, but radically different in its characteristics. This form of carbon due to the annealing process has been called temper-carbon by Prof. Ledebur, who first described it in connection with the malleable (Ger. "temper") process.

I will mention one of the peculiarities of this form of carbon. If a malleable casting which on fracture shows the fine black velvet surface, is heated up very high and then plunged, all this amorphous carbon is dissolved, and the fracture shows the grain of a good tool steel. The same is often seen when a piece is hammered cold, and more especially when a casting that has become warped is heated up and straightened. The grain in the latter instances will not be as good as in the first one, but it shows that to straighten a malleable casting no heat, and preferably pressure only should be applied. This characteristic of the carbon is often used to palm off malleable castings as steel ones, much to the disgust of the user and the producer of bona fide "malleable."

Of the properties of the malleable casting, it may be said in general that the tensile strength should run between 42,000 and 47,000 lbs. per sq. in. Castings showing only 35,000 are still quite serviceable for ordinary work. It is not advisable to run much beyond 54,000 lbs. per sq. in., for the resilience is reduced, and one of the most valuable properties of the malleable casting impaired. I have made much work running up to 63,000 lbs., by the plentiful addition of steel to the mixture in the open hearth furnace, but do not recommend this, as wherever such high results are wanted they can best be obtained by using the steel casting direct.

A an instance of what can be done with malleable castings, a series of tests was made with bars of small and large diameters, which were heated and carefully drawn out under the hammer. While the interior, or high carbon portion was badly cracked up, the surface was of such a fine material that in one sample the tensile strength actually ran up to 123,000 lbs. per sq. in. The elongation of a piece of good "malleable" will lie between 2½ and 5½% measured between points 2 ins. apart. The thicker the piece, the smaller the elongation.

In making the transverse test, the deflection of a piece 1 in. square, resting upon supports 12 ins. apart, should be over ½-in., the breaking weight being at least 3,500 lbs. Very soft iron often deflects 2½ ins. under this test, but this is exceptional and may not be reproduced continuously.

The high resilience, or resistance to shock, in "malleable" is its most useful characteristic. It is well known in railway circles that the ordinary steel casting comes nowhere near the malleable for service conditions. Only where an exceedingly high tensile strength is required, as in the car couplers for the heavy modern trains, is the malleable casting being gradually replaced. On the other hand, car castings, formerly made of gray iron, are now specified for malleable wherever possible, in the interest of greater strength and reduced weight. When we remember that the present production of malleable castings is at the rate of 650,000 tons per annum, and at least half of this goes into car construction, the importance of the industry may be properly gaged.

In spite of this enormous production, there is really little information available outside of the foundries most interested, and it may as well be said, also very little within. The founder is not going to increase the difficulties in his sales if he can help it, and the inspecting engineer, not being able to check the process from his own understanding, cannot act as intelligently as he really should. The American Society for Testing Materials is, however, at present at work on this, and we shall soon have a set of specifications governing the production of these castings where good qualities are essential, which will insure better work all along the line.

Before going into the composition of good "malleable," it is necessary to look a little into its structure. Originally cast to be perfectly chilled, that is with the carbon all combined, and a contraction of some ¼-in. to the foot; the annealing process serves to expel the carbon from its state of combination, depositing it between the crystals of the iron, not in the crystalizing graphite of the gray iron, but as an amorphous form not unlike lamp black. At the same time an expansion equal to half of the original contraction takes place, the net result being a shrinkage allowance for the pattern identical with that for gray iron castings of similar shape and thickness.

Beside this expulsion of the carbon from its combination, there is a removal of some of it from the outer portions of the casting. This amounts to nearly all in the skin and decreases to nothing at a depth of ¼-in. I do not take kindly to the generally accepted theory that oxygen from the packing penetrates the casting, removing the carbon by burning it out. I have always found that when oxygen has access to the interior, through the open structure of the iron itself, this is also oxidized with the carbon, and the whole presents a sorry sight.

It will be noted that owing to the removal of varying amounts of carbon from the skin to the interior no carbon determination of a malleable casting is of any value, unless the sample is taken before the anneal, and even then it is only good for the total carbon. For an annealed piece, a sample taken from the center of the fracture with at least ⅝-in. untouched around the drill would give a fair indication of the carbon contents, but cannot claim accuracy.

In former days of charcoal iron about 4% carbon was the rule in malleable castings. In these days of coke irons and steel additions to reduce the carbon, this may run as low as 2.75% before trouble ensues in the anneal, if not already in the foundry through excessive cracking and shrinkages. With the modern demand for a high tensile strength it is well to place the lowest limit at 2.75%, and the upper limit for common work would be found in the saturation point of this grade of iron, or, 4.25%. It is absolutely necessary that the hard casting be free from graphite, even a small amount of this indicates an open structure with consequent ruin to the work in the anneal from penetrating oxygen. To keep the carbon in the combined state is the function of the silicon percentage arranged for in the mixture, the rate of cooling due to the cross section, the pouring temperature, sand, etc.

The sulphur content is quite important, especially just now, when we are getting the sweeping of the coal mines for our fuel to a greater or less extent. The percentage should not be allowed to go over 0.05%, though double this may let a casting pass muster where good work is of no special object. Once the sulphur exceeds 0.05% trouble may be expected. It is therefore wise to hold the pig irons below 0.04% and to see that the fuel used is not too rich in sulphur.

Manganese is seldom troublesome, as it does not often exceed 0.40% in the mixture, which means 0.10 to 0.20% in the casting. Above 0.40% in the casting it begins to give trouble in the anneal, and therefore manganese as a general proposition should be kept low. Phosphorus should not exceed 0.225%, and is better kept below this.

To get the proper silicon limit for the class of castings to be made is the trick which means either success or failure for your foundry. This will be realized from the fact that you do not know how your castings will come out until about a week after they went into the anneal. Now suppose your mixture is wrong, and the silicon is either too high, which means "low" or rotten work, or too low in the castings, making them "high" (strangely contradictory but nevertheless shop terms in daily use and dating back to the times when silicon was unheard of in malleable works). This means hard burnt white castings stronger than the first mentioned class, but equally undesirable. You will not know of this until a whole week's work, in all probability equally bad, has been placed into the ovens, and comes out in its turn only to wander into the scrap pile. Naturally disaster stares the inexperienced founder of malleable castings in the face all the time, and only a good laboratory will keep him out of hot water, everything else being equal.

*Abstract of a paper read at the annual meeting of the American Foundrymen's Association at Milwaukee, Wis., June 9 to 11.

†Secretary American Foundrymen's Association, New York, N. Y.

It also shows the necessity for better protection to the buyer, who cannot be supposed to distinguish between a good and only fair casting.

In general we may say that the thicker the casting the lower the silicon allowable in order to get a white iron in the sand. Thus for the heaviest classes of work, the silicon of the casting should not exceed 0.45%. For ordinary work 0.65% is the point to be sought for. Agricultural work may run up to 0.80%, while the lightest casting may have 1.25% without danger, though it is not advisable to exceed this limit for anything.

Our American practice differs from the European in several respects. We have a comparatively short anneal, that is we aim at a conversion of the carbon rather than its removal. Over there it is desired to get all carbon out, so that a wrought iron casting, if it may be so called, may result. With much of the iron cast from crucibles, it is quite possible to make very fine grades of work, and this may account for higher prices for malleable than steel castings paid in some parts of Europe. Imagine, however, what would result if we had the crucible processes here, with our average production of some 35 tons daily in the larger plants, or some 80 in the very large ones.

The common American practice is to use the reverberatory, or "air" furnace, either with or without the top blast over the bridge to hasten the melting. There is always a blast introduced under the grates, unless indeed in our older works, the chimney draft is exceptionally good. About twelve years ago the open-hearth furnace was introduced into one of our largest works, and it was my good fortune to gain experience with it there. While not many malleable establishments have the open-hearth furnace, yet it is undoubtedly the most economical melter there is, provided several things. One is that it must be kept busy as much as possible, as only then its full economy is taken advantage of. Then skilled workmen must be kept in charge. This does not mean the steel melter with his habit of letting the heat take care of itself, and tapping a 10-ton heat five hours after charging, whereas it should come out in 2½ hours. But it means a man who will use his muscle freely to rabble up the heat, push the pigs into the bath as quickly as they can be cared for, mix his iron well, fire sharp and quick so that the process becomes one of melting only rather than a refining or burning out of large quantities of silicon and carbon. When these conditions prevail the open hearth will turn out a most excellent product.

Let us take fair conditions with three heats daily from a 10-ton open-hearth furnace. Using producer gas the fuel ratio is about one of coal to six of iron. In the reverberatory furnace the fuel ratio is one to four at best, and often only one to two. It is not advisable to make larger heats than 15 to 18 tons, as the time consumed in melting, and especially in pouring from the small ladles after tapping becomes so great that the bath is seriously damaged by undue oxidation and overheating. When the time comes for continuous melting in the malleable foundry, when heat after heat is taken off as fast as the bottom can be patched up and the furnace charged again, then will the complete economy of the open-hearth furnace be fully realized. We may then also see the tilting furnace of value to us, though a device of my own, which I am using successfully in my own interests and which allows the tapping from three spouts at different levels, successively, has the advantages of the tilting furnace for "malleable" without incurring the heavy first and running costs.

For making malleable castings, the open-hearth furnace should be pushed very hard for a time, almost sufficient to collapse it, then it should be checked before actual damage is done to crown and ports. It this way a short, sharp heat is obtained, the silicon of the heat may be calculated for a loss of 20 to 25 points, whereas from 35 upwards is the rule in other processes. Some 300 heats should be taken off before repairs of several days' duration are required, and a total of at least 1,000 heats only should necessitate practically a rebuilding with but little loss other than the refractories.

In the meantime there has been much improvement in the air furnace. Strange to say, while the composition (excepting only the phosphorus content) of the large roll and the malleable casting is the same, the air furnace used in each industry has been developed on different lines. In making rolls we find the short high reverberatory chamber, more on the lines of the copper furnaces; while in the malleable industry the furnace is long, very low and contracted at the stack entrance. While formerly the hearth was practically rebuilt after each heat, at the present day several heats are taken off before a new bottom it made. The bungs, of course, always suffer, and herein the crown of an open hearth is much more easily cared for. But the poor efficiency of the fuel is an inherent difficulty which cannot be overcome and presents new difficulties with every change of quality.

At the present time there is a general difficulty with the coal used, which means castings with an undue amount of sulphur. These castings are weak and will some day wander into the scrap pile. When the next slump comes we will be confronted with a serious condition. This high sulphur scrap will come into the market, in fact forced upon the founder wherever his castings can be identified. They will be hard to use by him, and from the fact of high sulphur will not be available for basic steel, as was the case formerly. A neat problem which will make the fortune of any one who may discover an economical remedy is the removal of sulphur from iron on a commercial scale.

The cupola still turns out a considerable tonnage of malleable castings, but this process will be gradually superseded by the furnace method, chiefly on account of the better grade of work turned out by the latter. There is, however, one interesting point connected with the cupola process, or rather with cupola iron, which we must go into more fully in connection with its bearing upon the anneal. Cupola iron requires some 200° F. more than furnace iron to anneal it properly. This is a general proposition. It seems strange that is should be so, but possibly the structure of cupola iron is so close that it requires more effort to get the crystals apart and to effect the liberation of the carbon from its state of combination. Whether this is due to the contact of the metal with the fuel as it trickles down in thin streams and drops is hard to say, but the difference certainly exists, and must be provided for in the anneal.

Naturally with a higher degree of heat the wastage of the annealing pots is more marked, and the process becomes more expensive in this regard also, for our annealing boxes must be reckoned as a dead loss which is to be diluted as it were by as long a life as possible in the ovens.

In studying the annealing process we find two extremes leading to about the same results, so far as the carbon change is concerned. A short anneal at a very high heat is as effective as a comparatively long anneal at a much lower temperature. That is to say, we can anneal, or rather change the carbon in a casting by placing it over night in a melting furnace which has been let cool below the melting point of the iron, or do the same thing in the annealing oven at a much lower temperature, but giving it a week's time. Of the two methods the latter is by far the preferable, as it not only permits the change in the carbon, but also gives the carbon time to get out. Then again the chances of burning the castings in the anneal are obviated. The result is a good, reliable casting, while in the hurry-up processes one never knows whether they are annealed at all. Malleable founders, therefore, while experimenting for generations on short annealing lines, have come to recognize that the best all around and safe method is to arrange matters so that an oven may be regularly recharged on the same day of each week.

We may describe the annealing process by a curve which runs up quickly, remains horizontal for a short time, and then drops very gradually. That is a sharp heating up, in the shortest safe time possible, then a shutting off of the dampers and maintaining of the temperature evenly for a period of say two full days at least, and then a gradual cooling down to at least a black heat before dumping. Here is where mistakes are often made, annealing pots being drawn red hot because some particular casting is wanted badly. The castings are red hot when the air touches them, the delicate reaction of the carbon is disturbed and an inferior material results. I have always had softer, more malleable iron from the anneals which had the extra Sunday to become cold in the oven, and were cold when dumped on Monday morning.

An oven can be brought up to heat as quickly as may be, the fuel waste to do this being alone considered. In cities where the smoke problem exists, more time is required than in the open country. For a fair-sized oven at least thirty-six hours are required to bring it up to heat (a pyrometer should always be used to test this), and then it should be held there.

As to the actual temperatures there is this much to say. Furnace iron of average thickness must have received over 1,250°F. after coming up, until cutting off the heat, to be safely annealed. Perhaps even then some of the work must be put back for another anneal. A safer limit is 1,350°F., and no more is necessary. This temperature must exist in the coldest part of the furnace, or usually at the lower part of the middle in the front row pots. As a rule the upper surface of an oven is some 200°F. higher than this, although I have succeeded in building ovens in which there was but a difference of 100°F. throughout the whole interior space, the temperatures being measured with a LeChatelier element 20 ft. long.

Translating these temperatures we find that 680°C. is the lowest point for successful annealing of furnace iron, while 780°C. is the safest one. For cupola iron the temperature should be about 850°C.

THE DEVELOPMENT OF THE COMMERCE OF THE GREAT LAKES.*

By Afred Noble, President, Am. Soc. C. E.†

In selecting a subject for this occasion, it has seemed to me that I would be more likely to interest you in a topic of specific engineering and commercial development than in one of those broader subjects, always of interest to professional men, which have been treated so ably by my predecessors. The example I shall present is one with which I have happened to be in contact more or less for more than thirty years. This development is largely the result of engineering work, and thus its study is in our field. I shall therefore ask your indulgent attention to such facts and conclusions as I may present regarding the Development of the Commerce of the Great Lakes. In the main, I shall confine myself to the portion of the Great Lakes System lying above Niagara Falls, which forms a well-defined unit.

THE FIRST ATTEMPTS AT LAKE COMMERCE.—In the light of more recent history, it seems at first surprising that so much time has elapsed after the occupation of tropical America before serious attention was given to that part of the continent where the greatest development has since been made. In Spanish America, a high degree of civilization, for the time, had been reached before the English had obtained a foothold in North America; and the French, as a civilized community, had little more than standing room along the margin of the St. Lawrence more than a century after the great achievement of Columbus. Much information concerning the areas immediately bordering the Lakes was given by the missionaries, who left admirable records; and some information of the regions further inland was obtained by the coureurs-de-bois, who made few records; but the Mississippi Valley was practically unknown until nearly two centuries after Columbus, when La Salle undertook his heroic task. As a first step he became a shipbuilder.

The launching, in 1679, of La Salle's schooner, the Griffin," a vessel of about forty-five tons, marked the inauguration of modern navigation on the Lakes above the Falls of Niagara. A little hamlet, at the mouth of Cayuga Creek, a short distance above the falls on the American side, bearing the name of the intrepid explorer, marks the site of the first shipyard on the shores of these waters.

It was expected that the "Griffin" would serve to advance the exploration, not only by conveying La Salle and his party to Lake Michigan, but by engaging in the fur trade its profits would supply in large part the money needed to sustain his work. After landing on the shore of Green Bay, he loaded the vessel with furs and sent it on its way to the foot of Lake Erie. It was never again heard from. Whether it disappeared through the fury of storms, treachery of the savages or cupidity of its own crew, is one of the mysteries of these inland seas. This seems to have been the only attempt to place a modern craft on the lakes for many years. I have been able to find no record of any other vessels on Lake Erie until after the capture of Fort Niagara by the British in 1759, when they began at once to build vessels above the falls.* During the siege of Detroit by Pontiac, in 1763, two small vessels, the "Gladwyn" and the "Beaver,' lay at anchor in front of the post; thus it would appear that nearly another century had passed—or nearly three centuries after Columbus—before modern navigation was resumed on the lakes between the Falls of St. Mary and the Falls of Niagara.

Such commerce as existed on the Great Lakes in those early days was mostly confined to the trade in furs, and converged at Montreal, the head of ship navigation on the St. Lawrence. This was carried on the Lakes mainly in canoes and craft 30 to 50 ft. long, propelled by paddles, called barges by the English and bateaux by the French.

From such meager records as are at hand it seems probable that, after the unfortunate "Griffin," sail navigation had an earlier development on Lake Superior than on Lake Erie. It appears, indeed, that a Frenchman named La Ronde built a bark of forty tons above the St. Mary's Falls or Rapids about 1731, the rigging and other materials being sent from Lower Canada in canoes.† It is stated by Captain Jonathan Carver, who traversed Lake Superior in 1766, that the French, "while in possession of Canada, kept a small schooner on this lake." The loss of this vessel is reported soon after the conquest of Canada by the British.‡ The discovery of copper led to the building of a sloop of 70 tons, above the St. Mary's Falls, which was launched in 1772. It was used in prosecuting mining enterprises until their collapse a year or two later, when it probably passed into the hands of the fur traders who from this time monopolized the commerce of Lake Superior for many years.‡

THE DEVELOPMENT OF THE GREAT FUR COMPANIES.—The early history of Lake commerce could not be understood without a reference to the remarkable commercial organizations which were formed mainly for the trade in furs. The first and most important was the Hudson Bay Company, which was chartered by Charles II in 1670 under the name of "The Governor and Company of Adventurers of England trading into Hudson Bay." It had the exclusive right to trade in and govern all the territory draining into Hudson Bay. For more than a century it exercised these privileges without opposition.

*President's address delivered at the annual convention of the American Society of Civil Engineers at Asheville, N. C., June 9, 1903.

†30 West 34th St., New York City.

*"The Commerce and Shipping of the Great Lakes." A special report by Mr. C. H. Keep, of Buffalo, N. Y.

†Dr. James D. Butler, in a paper for the Michigan State Historical Society, on "Early Shipping on Lake Superior."

‡Butler.

except as operations brought its agents in contact with the French, then in control of the basin of the Great Lakes. Soon after this territory passed under British control, in 1763, the superior advantages of the Lake Superior route to the region northwest of it became manifest. In 1783, the year when the Independence of the United States was acknowledged by treaty, the Northwest Company was organized at Montreal, and at once became a vigorous competitor of the older company, extending its operations across the continent. Its success stimulated the formation of other companies, among others the American Fur Company, a pseudonym for John Jacob Astor. The interests on the British side of the boundary were practically unified in 1821 by the amalgamation of the Hudson Bay and Northwest companies under the name of the former. About 1870 the company gave up its power to govern the vast territory over which it had so long held absolute sway, and became a purely commercial organization. Its business is said to be greater now than ever before.

The Northwest Company employed sailing vessels soon after it was organized, and before the end of the 18th century had at least one on Lake Superior and one on Lake Huron. At the beginning of the war of 1812 the company reported to the Canadian Government that they would place at its disposal on Lake Superior one vessel of 120 tons which could carry six or eight guns, and another of 60 tons. These and three others were captured by the Americans; and another, cleverly hidden in an obscure harbor at the east end of Isle Royale, escaped detection, and after the close of the war was run down the St. Mary's Rapids for service on Lake Erie.*

The year after the war closed, Congress passed an act prohibiting British fur traders from prosecuting their enterprises within the territory of the United States. This gave the American Fur Company its opportunity, and, before many years had elapsed, it had sailing vessels both above and below the St. Mary's Rapids. It is not certain that the British companies again placed sailing vessels on Lake Superior.

The British, however, were not entirely driven from the lake. They had a schooner in service in 1822 and 1823, in which Lieutenant Bayfield, of the Royal Navy, made a survey of the lake. Considering the time consumed and the means at hand it was wonderfully well done. The shore line and depth of water, islands and sunken rocks, were represented with surprising accuracy and detail, and Bayfield's charts remained standard for fifty years.

While the British had sailing vessels on Lake Erie in 1759, and probably continuously thereafter, no American vessel was built above the Falls of Niagara until 1797, when the schooner "Washington" was launched at Erie. It was sold the following year to a Canadian, and carried on wheels around the falls to Lake Ontario.† There were no other American vessels on Lake Erie for some years, but, at the outbreak of the war with Great Britain, several small ones were found in service on both sides of the boundary and formed parts of the hostile fleets. The larger vessels of Perry's fleet were built at Erie in 1813. It is said that they were built from standing timber in seventy days. The famous battle of Lake Erie, fought on September 13, 1813, gave the Americans supremacy on these waters, and it has been maintained ever since. It is worth noting that the aggregate tonnage of the two fleets in this celebrated battle was less than that of a modern lake freighter of moderate size.

After the war, the tide of emigration set strongly to the territory bordering on the Lakes. Sailing vessels multiplied, and in 1818 the first steamboat above Niagara Falls was launched at Black Rock, now a part of Buffalo, then the principal Lake Erie port, and on August 25th started on its first trip to Detroit. With great propriety, it was named "Walk-in-the-Water," for it appears to have been capable of no more rapid pace. From nine to ten days were required for a round trip. The port of Black Rock was on the Niagara River, below the rapid current, at the outlet of the lake. Unassisted, the "Walk-in-the-Water' could not stem the current and was regularly assisted, when starting on its westward trip, by what was called a "horned breeze," several yoke of oxen being attached to the boat and hauling it to the lake.‡

THE ERA OF CANALS.—An event was now approaching which was to have immediate and far-reaching industrial results. This was the opening of the Erie Canal, giving convenient access to the lake region and an outlet for its agricultural product.

It appears probable that a canal to connect Lake Erie directly with the Hudson River was first proposed by Gouverneur Morris in 1803, but the suggestion was considered "the effusion of an eccentric mind indulging in romantic and visionary schemes." Within four or five years its merits became more generally perceived, and in April, 1808, an act of the Legislature of New York authorized a survey of the route, and appropriated for it the magnificent sum of $600. Mr. James Geddes was appointed the first engineer, made the survey and submitted his report early in the following January. It did not include an estimate of cost, but this was supplied two years later by a State Commission as $5,000,000. A loan of the amount was authorized by the Legislature, but the act was subsequently repealed.

The commission referred to was composed of some of the most eminent citizens of the State. After submitting its report, with the estimate above noted, its membership was increased, and a second report was made in 1812. From this time, for several years, nothing decisive was done, but the sentiment in favor of the project was gathering strength, and in 1816 a Board of Canal Commissioners was appointed, who employed engineers, fixed the dimensions of the prism and locks and inaugurated the work, breaking ground at Rome, July 4, 1817. The President of the Board was De Witt Clinton, the most powerful and persistent advocate of the project.*

A few month before the inauguration of the work at Rome, a joint committee of the Legislature reported that the cost of transportation from Buffalo to Montreal was $30 per ton, and the returning transportation from $60 to $75. The expense of transportation from Buffalo to New York was stated at $100 per ton, and the length of passage twenty days. In 1852 Mr. Israel P. Andrews, in a striking "Report on the Trade and Commerce of the British North American Colonies and upon the Trade of the Great Lakes and Rivers," commented on these rates in the following forcible words:

> Upon the very route through which the heaviest and cheapest products of the West are now sent to market, the cost of transportation equalled nearly three times the market value of wheat in New York; six times the value of corn; twelve times the value of oats; and far exceeded the value of most kinds of cured provisions.

These comparisons show how absolutely impossible the development of the Northwest would have been at that time without the cheaper transportation afforded by the canals.

Among the most effective reasons given for the building of the Erie Canal was the need of counterbalancing the advantages of the natural route down the St. Lawrence. In a memorial, presented to the Legislature in 1816, commenting on the route proposed by way of Lake Ontario, it was said, "the most serious objection against the Ontario route is, that it would inevitably enrich the territory of a foreign power at the expense of the United States."* Indeed, the battle between the Northwest and New York, the one contending for the cheapest outlet to the seaboard, the other for a waterway through its own territory and for the development of its own wealth, was fairly joined at that early day. With the Erie Canal, victory was secured for the Empire State, and the supremacy of the port of New York established for at least a century.

These consequences followed from a ditch that at the present time seems insignificant. The bottom width was 28 ft., at the water surface 40 ft. Its depth was 4 ft. The locks were 90 ft. long and 12 ft. wide. The magnitude of the canal is well set forth in a record of time: "Three Irishmen finished three rods of canal, 4-ft. cutting, in 5½ days."† It was opened through to Lake Erie on October 26, 1825, and navigated by boats of 35 to 45 tons. It had cost about $7,000,000.*

The building of the Erie Canal stimulated the spirit of enterprise in neighboring States, and in 1825 the State of Ohio began a canal system, connecting Lake Erie with the Ohio River, and, by branches, with various points within the State. The main lines were completed in 1832. The system attained a total length of nearly 900 miles, and in 1852 their total cost had amounted to more than $15,000,000; their width at bottom was 40 ft. and their depth 4 ft., the same as the Erie Canal. In 1826 the State of Pennsylvania inaugurated the great Pennsylvania line of improvement—part railroad, part canal—extending from Philadelphia to Pittsburg, with branches connecting with Lake Erie via Ohio canals and directly with Lake Erie at Erie.‡

The Wabash and Erie Canal, by which the interior of Indiana was brought in water communication with Lake Erie at Toledo, gave an outlet to the corn crop on which northern Indiana depended, and made Toledo for many years the chief shipping point of this staple. It was 60 ft. wide and 4 ft. deep, east of Fort Wayne, and 40 ft. × 3 ft. westward.§ A water communication between Lake Michigan and the Mississippi was advocated from a very early day; the Illinois and Michigan Canal was commenced in 1836, and opened in 1848, with a channel 60 ft. wide and 6 ft. deep, and provided for boats of 150 tons. Its summit level was only 8 ft. above Lake Michigan.† A second line of communication between these waters was begun in 1848, to connect the Fox and Wisconsin Rivers, the former discharging through Green Bay into Lake Michigan, the latter into the Mississippi, with headwaters only two miles apart.

None of these canals connecting the Great Lakes with tributary districts is now an important factor in Lake commerce. Some have been sold, others have been retained in use, but with diminishing traffic and a constant expense to the communities owning them.

As the opening of the Erie Canal drew near, the improvement of Lake harbors became most urgent. The Port of Buffalo was soon to take first place as the terminus of the canal. A survey of the harbor was made by the State engineers in 1819, but it was perhaps due to the prominence given the neighboring harbor of Erie, in the war then just passed, by the building of Perry's fleet, that the latter was the first Lake harbor to receive an appropriation from the general government. By act of Congress, approved March 3, 1823, an appropriation of $150 was made for a survey of the harbor of Erie, which was carried out under the direction of the Corps of Engineers of the Army, and plans for the improvement were presented by a board of engineers on the 4th day of October following.

By act of Congress approved May 26, 1824, the sum of $20,000 was appropriated for the work, and operations were commenced the same year. This appears to be the earliest appropriation made by the General Government for harbor improvements. Much doubt existed as to the constitutional right of Congress thus to dispose of public money. Appropriations for other harbors soon followed, but the entire amount for the Lakes above the Falls, up to the end of 1829, was less than $250,000. In the next decade the total was $1,250,000; in the next, about $400,000; in the decade of the '50's, less than $500,000, and in the period from 1860 to 1865, inclusive, embracing the Civil War, the total was but little more than $500,000. The period of larger appropriations began in 1866.

Another impetus was given to Lake commerce in 1829 by the opening of the Welland Canal, in Canada, between Lakes Erie and Ontario, by which the obstruction to navigation toward the sea, by the Falls of Niagara, was at last overcome. The first vessels through it ascended from Lake Ontario, one of the first two being of 85 tons burthen. The canal and locks permitted the passage of vessels drawing 7½ ft., with beam of 21½ ft. An extension giving more direct communication with Lake Erie was commenced immediately, and opened in 1833. The work had been executed by a corporation assisted by the governments of Upper and Lower Canada. Immediately after the union of these provinces, in 1841, the Government acquired all the stock and took up the task of completing the canal system to tide-water at Montreal. The Welland was enlarged, and, at the end of 1848, the St. Lawrence navigation had been improved to such an extent that vessels drawing 9 ft. of water could pass from Lake Erie to the sea. The locks were generally 150 ft. long and 26½ ft. wide.* Numerous sailing vessels and steamboats were built whose dimensions were fixed by these lock dimensions. When I first became acquainted with Lake commerce, in 1870, a large share of the vessel tonnage consisted of so-called "canal vessels" built to run between ports on Lake Ontario and the Upper Lakes. These were mostly sailing vessels, but there were also many steamboats, a single line having about thirty in constant service. Some of the sailing vessels are still in use.

It is beyond the scope of this address to make more than a reference to the magnificent system of waterways by which, as now developed, vessels drawing 14 ft. can pass from the Great Lakes to tide-water at Montreal. On this development the Government of Canada has expended $67,000,000,† a far greater amount in proportion to its resources than the Government of the United States has expended on all its waterways.

It was evident very soon after the opening of the Erie Canal that it must be enlarged, and only ten years afterward the enlargement was commenced. Its execution required 27 years, and was completed in 1862, giving a prism 56 ft. wide on the bottom and 7 ft. deep, with locks 110 ft. long and 18 ft. wide, allowing the passage of boats carrying 240 tons of freight. The enlargement had cost $32,000,000.‡ In 1895 a further enlargement, giving 8 ft. over the miter-sills and 9 ft. in the prism, was inaugurated, but suspended because of the unexpectedly great cost.

The effect of the opening of the Erie Canal on Lake commerce was immediate; in fact, as the completion of the waterway drew near, its advantages were to some extent anticipated.

In 1816 the whole tonnage of the Lake vessels at all the

TABLE I.—Showing Growth of Lake Shipping.

	Tons.
In 1825, the year of the opening of the Erie Canal, the tonnage above Niagara Falls consisted of three steamers of	772
And 54 sailing craft of	1,677
Making a total of	2,449
In 1830 this had increased to	16,300
" 1835 " " " "	30,692
" 1841 " " " "	55,181
" 1846 " " " "	90,000
" 1851 " " " "	153,426
" 1862 " " " "	*383,309

*But this includes the tonnage below the Falls of Niagara.—Keep.

*Butler.
†Keep.
‡Keep.

*The data relating to the early history of the Erie Canal have been extracted mainly from a "Documentary Sketch of the New York State Canals," by S. H. Sweet, Deputy State Engineer and Surveyor, 1862.
†Sweet.
‡Andrews.
§Andrews.

*Data regarding the Welland Canal and the St. Lawrence Canal are obtained from "General Report of the Commissioner of Public Works," of Canada, for 1867.
†Report of Department of Railways and Canals, 1901.
‡Sweet.

Lake Erie ports, including Detroit, was 2,067 tons. The vessels ranged from 10 to 99 tons, except two, which were 102 and 134 tons, respectively.

In 1819 there were registered in the customs district of Buffalo Creek seven vessels, with a total tonnage of 473 tons, but of these seven vessels one was a steamer* (none other than the redoubtable "Walk-in-the-Water").

The increase in shipping, from this time forward, was too rapid to be followed in detail here. The growth during the next few decades is summarized by Andrews in the accompanying Table I.

The dimensions of vessels had also increased rapidly. In 1839 the 25 largest steamers had an average burthen of 449 tons, the largest one being of 800 tons. In 1851 the average of the 25 largest was nearly 1,000 tons, and of the whole steam fleet, of 157 vessels, 437 tons. The most remarkable feature of the period from 1840 to 1860 was the development and decline of the passenger traffic. A number of boats engaged in this traffic were of 1,000 tons and upward. The "Western Metropolis," owned and operated by the Michigan Southern & Northern Indiana R. R. Co., was 340 ft. long, and was run regularly at 19 miles per hour. Its route was between Buffalo and Toledo, the Lake Shore R. R. not having been completed. On the opening of that road, affording an outlet for the Michigan Southern & Northern Indiana, and the opening of the Great Western of Canada, giving the Michigan Central an outlet, the passenger traffic quickly declined, the engines were removed from several steamers, and the hulls converted into sailing vessels, and in some cases into dry docks. It was not until very recent years that these steamers were equalled on the Lakes, either in dimensions, speed or elegance of equipment.

Up to 1836 the direction of grain shipments through the Straits of Mackinaw was toward the west. In that year the first cargo of grain from Lake Michigan was received at Buffalo, and by 1840 this traffic had become securely established. Chicago quickly took first place as a shipping point, its shipments increasing from 10,000 bushels in 1840 to upward of 28,000,000 in 1860. The present grain movement of the Lakes is about 200,000,000 bushels annually. In recent years, however, this movement, once the largest item in Lake commerce, has taken a place second in importance to iron ore from the Lake Superior ranges.

THE DEVELOPMENT OF COMMUNICATION BETWEEN LAKES HURON AND SUPERIOR.

It is not generally known that canal communication was opened between Lake Superior and Lake Huron many years before the Erie Canal gave an outlet to Lake Erie. In fact, it was long forgotten that such a channel had ever existed. A few years ago, Judge Joseph H. Steere, of Sault Ste. Marie, a gentleman whose recreation has consisted largely of study of the history of former conditions in the Lake Superior region, found in some old records a mention of a canal and lock formerly existing on the Canadian side of the St. Mary's River at the rapids. He called to his aid a fellow townsman, E. S. Wheeler, M. Am. Soc. C. E., and they made jointly a search and were rewarded by finding the remains of this the earliest of the artificial waterways about the Great Lakes. It was built by the Northwest Company, about 1798, to facilitate the passage of bateaux engaged in the fur trade. Many canoes and sailing vessels have been run over the rapids since the white man first appeared on these waters, and the lives of passengers and crews cheerfully risked, but the consigning of valuable furs to such hazards was a more serious matter. The lock was 38 ft. long, 8 ft. 9 ins. wide, with a lift of 9 ft., which was about one-half the total fall at the rapids. The canoes and bateaux were assisted over the remainder by oxen. The lock served its purpose for several years, but was finally destroyed by the Americans in 1814, during the war with Great Britain. A public-spirited resident of Sault Ste. Marie, Canada, has partially restored it, and gives it sympathetic care.

Soon after the full tide of immigration set in to the Lake region the Lake fisheries assumed prominence. Very soon the resources of Lake Superior in this direction attracted attention, and better communication with the Lower Lakes was demanded. The St. Mary's Rapids, with a fall of about 18 ft. in a distance of less than a mile, formed the only serious obstruction for the vessels of the time, and attention had been called to the necessity of a ship canal around the rapids, by the first governor of the State of Michigan, in his message to the first Legislature of the State, in 1837. The Legislature authorized a survey and appropriated $25,000 to cover the expense. The survey was made the same year, and plans prepared for a canal 75 ft. wide and 10 ft. deep, with locks 100 ft. long and 34 ft. wide. These dimensions were greater than had been adopted for any other canal in the country. The cost was estimated at $112,544. Financial difficulties prevented the State from undertaking the work, and Congress was repeatedly but vainly besought to undertake it. In 1840 a bill was before Congress granting the State 100,000 acres of land to aid in the construction of such a canal. It was advocated mainly on the ground that it "would stimulate the fisheries of Lake Superior, estimated to be worth $1,000,000 per annum"; and it was incidentally added, "in the country bordering the southern shore of Lake Superior copper ore and other minerals are believed to exist in abundance." While the bill was before the Senate, "Mr. Clay, of Kentucky, took occasion to speak of the work as beyond the range of the remotest settlements in the United States, or in the moon." Possibly the great senator, in preventing the inauguration of the work on a ridiculously inadequate scale, performed not the least of his many public services.

The existence of copper in the country adjacent to Lake Superior was known from a very early day, and was mentioned by Lagarde in a book published in Paris in 1636.† Other references soon followed. A more detailed account was given by Charlevoix, in the report of his journey made in 1721. Captain Jonathan Carver, whose voyage in 1766 has been mentioned, stated:

> The Ontonagon River is remarkable for the abundance of virgin copper on and near its banks, a metal which is met with also in several places on the coast. I observed that many of the small islands, particularly those on the eastern shores, were covered with copper ore.

His book was, justly, perhaps, regarded by many as a second edition of "Gulliver's Travels," and subsequent explorations failed to confirm the truth of many of his statements, which appear to have been merely the creations of a vivid imagination.

Another traveler, Alexander Henry, reported that he saw copper on the banks of the Ontonagon River in 1765, and, on a second trip to the same locality, cut off from a large mass with an axe a portion said to weigh 100 lbs. A company was formed soon after, of which Henry was a leading member, to prosecute copper mining, a sloop built, as already stated, and miners sent to the site of the supposed mine. After one or two years of struggle at this site and at others, the enterprise was abandoned and little was heard of the mineral wealth of the Lake Superior region for 60 years or more.

One of the earliest measures taken by the State of Michigan, after its admission to the Union, was to provide for a geological survey. The work was placed in the hands of Dr. Douglass Houghton, one of the leading geologists of his time. He had already, in 1830 and 1831, visited the site of Henry's mine on the Ontonagon River, and again did so in 1840 while making his first geological survey. His reports "cleared up the mists of tradition, and attracted the attention of the people of the United States and of Europe to the new mineral fields. [He] fell a victim to the fury of the lake. His work resulted in the organization of numerous companies for mining copper. The first miners to visit the region after Henry's party in the previous century, went up the Ontonagon River in 1846 to remove the copper rock, which they succeeded in doing and in selling. It had been removed from Government land without license, and therefore was seized and taken to Washington, where it is believed to still remain. During the same year mining under proper licenses was commenced at several sites, and the mining interests became at once a more potent influence than the fisheries, for better communication with the Lower Lakes.

It would be difficult to determine now whether copper or iron was the more powerful factor in securing such improved communication. Rumors of the existence of iron ore had been heard before its discovery by white men. They were placed on an authoritative basis by William A. Burt, Deputy United States Land Surveyor, the inventor of the solar compass. In September, 1844, he was engaged with a party in making land surveys, for the United States Government, in the region since known as the Marquette District. They began to notice remarkable variations of the magnetic needle which changed rapidly as they moved from place to place. Finally, they came to a place where the north end of the needle pointed south of west, and all hands stopped work and looked about for the cause; soon they had collected from outcrops numerous specimens of iron ore. The first iron mine in the district was located the following year, and in 1846 the first iron from Lake Superior ore was made in a blacksmith's forge. The first shipment of ore from Lake Superior was made in 1850 and consisted of five tons. No great development could be made without continuous navigation to the Lower Lakes; yet the impulse for better communications had resulted in navigation on Lake Superior itself on what may be considered a commercial scale.

A notable event had occurred in 1839, when "The Algonquin," a schooner of 50 tons, was hauled overland past the rapids, and launched in Lake Superior. The development of copper mining furnished the impulse for repeating the feat, and several sailing vessels made the transit in 1845. In the same year the propeller "Independence," 280 tons, was hauled over, and other steamboats followed; small sailing vessels could not compete with them advantageously, and several were run over the rapids to end their days in the Lower Lakes. In 1852, two steamers and four propellers were reported as employed on Lake Superior. Goods, arriving at Sault Ste. Marie from either directions, were unloaded, transferred by teams and wagons or by tram cars past the rapids and reloaded on vessels. The cost of this was too great to be borne by any but valuable articles, and, while copper could bear the expense, the shipment of iron ore was impracticable. In 1850 the total of shipments across the portage was 6,000 tons. These were largely increased during the next four years immediately preceding the opening of the St. Mary's Falls Canal.

As often the case in later days, when a project of harbor or river improvement of questionable merit is pressed in Congress, a survey of the proposed St. Mary's Falls Canal was ordered, while an appropriation for the project itself was refused. From this resulted a better understanding of the commercial requirements and of the probable cost, and in 1852 Congress granted to the State of Michigan 750,000 acres of public land, requiring that the canal should be at least 100 ft. wide and 12 ft. deep, with locks at least 250 ft. long and 60 ft. wide. The lock dimensions were wisely increased to 350 × 70 ft., before construction began, there being two lifts of 9 ft. each. These dimensions were greater than in any other artificial waterway on the continent, if not in the world. Congress allowed three years for beginning the work and ten years for completion.

The State at once made arrangement with a corporation known as the St. Mary's Falls Ship Canal Co. for building the canal for the land grant. The undertaking was, for the times, stupendous. The locality was almost as uncivilized, the resources of the surrounding country were almost as undeveloped, as when white men first set eyes upon it two centuries before; but the work was in the hands of able men, and notwithstanding the isolation of the place, and, at the outset, the utter lack of labor, machine shops and all other facilities, and notwithstanding an outbreak of cholera which decimated the force, the work was executed in two years, and opened to commerce by the State on June 18, 1855. The period allowed by Congress for beginning sufficed for its triumphant completion. Its cost to the constructing company had been, in round numbers, $1,000,000.*. An amount of land equal to that granted by Congress could have been bought at the lawful rates for less money, but the Ship Canal Co. had the valuable privilege of selecting lands not yet thrown upon the market, and this privilege they exercised with great wisdom and great good fortune. A notable example was the site of the famous Calumet and Hecla copper mine.

The building of the canal marked a stage in the development of Lake commerce hardly less important than the opening of the Erie Canal, 30 years before; not only because of the traffic through it, which, indeed, increased slowly, for the country about Lake Superior was still a wilderness and there were no great wheat fields beyond it, but because it fixed for many years the depths to be obtained in the harbors and in the channels connecting the Lakes, and, consequently, to a large extent, the dimensions of vessels and the cost of transportation. The depth of water in but few of the Lake harbors was as much as 12 ft., while in the channels connecting the Lakes there were serious obstructions. In the St. Mary's River a channel several miles long had to be dredged before the limited commerce to and from Lake Superior could make use of the full draft provided at the canal; while the St. Clair Flats interposed a like obstacle to the far greater commerce passing there. The Civil War soon absorbed the energy of the country, and other interests were secondary.

At the close of the Civil War the principal articles transported by water were grain and lumber. The receipts of grain and flour at Buffalo in 1866 were about 1,500,000 tons; the receipts of lumber at Chicago alone were about 1,400,000 tons by Lake, while the iron ore shipments at all Lake ports were less than 300,000 tons, and the coal tonnage but a little greater than that of iron ore. A more liberal policy toward internal improvements was then adopted by the General Government, and projects for harbor and channel depths of 12 ft. were prepared and soon executed. This depth sufficed for only a few years. By 1870, or soon after, vessels drawing 13 ft. and upward could enter a few of the more important ports, such as Buffalo, Cleveland and Chicago, and a demand for a depth of 16 ft. became general. The initiative was again taken at the St. Mary's Falls Canal by a project for increasing the depth from 12 to 16 ft. and building a new lock, 515 ft. long and 80 ft. wide, overcoming the entire difference of level of about 18 ft. by a single lift. These dimensions were unprecedented in canal construction. A distinguished professional visitor from the other side of the boundary declared with something like indignation, that this was not a canal lock but a basin. The Welland Canal was then being enlarged, with locks 270 × 45 ft. and about 14 ft. lift. The lift of 18 ft. was almost universally criticised as unprecedented and injudicious. The improvement begun in 1870 was completed in 1881, at a cost of $2,200,000, but, before the increased depth could be made fully available, the St. Mary's River had to be deepened in numerous places, the St. Clair Flats Canal dredged and a cut made through a reef of rock near the mouth of the Detroit River. The last-named improvement was noteworthy by reason of the methods adopted for subaqueous rock excavation. The cost of the excavation had been estimated by a board of engineers at $30 per cu. yd., but the ingenious devices and methods of a single con-

*Keep.

*See "History and Review of the Copper, Iron, Silver, Slate and Other Material Interests of the South Shore of Lake Superior," by A. P. Swineford, Marquette, Mich., 1876.

†Swineford.

*$999,802.46.

tractor resulted in a lowering of prices to $7. Similar work has since been carried out at one-third of this figure with large profit.

The 16-ft. channel was completed in 1884. In the meantime the principal harbors were put in readiness and a fleet of large vessels was built to take full advantage of the new facilities. The growth of traffic had been notable. The average annual receipts of grain at Buffalo had increased about 50%. The shipment of coal by Lake at the beginning of the period was almost nil; at the end it was 3,000,000 or 4,000,000 tons, or more than half the entire Suez Canal traffic. Iron ore shipments had increased from 300,000 tons in 1866 to 2,300,000 tons in 1884. The number of vessels on the Lakes had increased but slightly, but the gross tonnage had increased about 50%. Freight rates had fallen remarkably; on iron ore from Lake Superior to Lake Erie ports they had fallen from $3 to $1.35 in gold per ton, and on wheat from Chicago to Buffalo from 9 to 2¼ cts. per bushel. The net registered tonnage through the St. Mary's Falls Canal had increased 440%.

Before the project for a 16-ft. navigation had been fully carried out, it was clearly seen to be inadequate and measures were taken for increasing it. Largely through the foresight of a member of this Society, General Orlando M. Poe, now deceased, then in charge of harbor and river improvements between Lake Erie and Lake Superior, the new work was undertaken on a liberal scale. A depth of 19 to 21 ft. is now found in the principal harbors and in the connecting channels between the Lakes. A new channel was opened through the system of small lakes and straits known as St. Mary's River, saving 11 miles in distance, and practicable for night navigation.

The extent of the improvements in the connecting channels is much greater than generally realized. Between Lakes Superior and Huron the aggregate length of new or deepened channels is 20.3 miles, and between Lakes Huron and Erie 21.2 miles. The commerce between Lake Superior and Lake Erie, aggregating 25,000,000 to 30,000,000 tons per year, passes through all of these, a total of 41.5 miles of artificial waterway. This is five miles greater than the length of restricted waterway to be made at the Panama Canal. The width of the Lake channels, however, is greater than now proposed for the Inter-oceanic Canal, varying from 300 to 1,000 ft., excluding a distance of about a mile at the St. Mary's Falls Canal, where the minimum width is about 115 ft., and a mile at the foot of Lake Huron, where the width is 2,400 ft.

These improvements included the deepening of the St. Mary's Falls Canal to 25 ft., and the building of a new lock, 800 ft. long and 100 ft. wide, with 20 to 22 ft. over the miter-sills, located on the site occupied first by the old State locks. It was opened to navigation in 1896. The cost of the Canal improvement was $3,800,000. This is the largest lock in existence, and, like its predecessors at the same place, was intended to pass three or four of the largest vessels at once. As in the previous cases, this expectation was not realized by reason of the rapid growth of ship dimensions.

While this lock was building, the Canadian Government decided to have a canal on their own side of the river, and built it at a cost of $4,000,000. The canal and locks give a depth of 22 ft. The locks are 900 ft. long and 60 ft. wide. It was opened to navigation in 1895. The lockage facilities at the St. Mary's Rapids now comprise three independent locks, each overcoming the entire difference of level at the rapids, and each equipped with hydraulic or electrical machinery for all operations. The last built American lock, opened in 1896, passes about 70% of the entire amount of commerce entering and leaving Lake Superior.

THE MAGNITUDE AND CHARACTER OF GREAT LAKES COMMERCE.—The amount of commerce passing through these improved waterways almost challenges belief. The Detroit River, undoubtedly, carries more tonnage than any other navigated channel in the world, the freight tonnage being estimated at 40,000,000 to 50,000,000 per year. St. Mary's River, with its freight tonnage of nearly 36,000,000 in 1902, may be the second. Of the leading articles transported, grain receipts at Buffalo increased nearly 300% from 1884 to 1898, the receipts there in the year last named being nearly 270,000,000 bushels,* or about 7,000,000 tons. The coal movement is somewhat greater, while the movement of iron ore is three or four times as much as either. Several lessons of importance, in the design of ship canals, are taught by experience with these waterways, which are peculiarly applicable to the project for an Isthmian Canal.

One of these lessons is that a very large traffic can be carried through a canal with locks. During the navigation season of 1894, embracing 234 days, a tonnage of 16,800,000 tons, net register, was passed through a single lock, the vessels averaging less than 940 tons each. During the last season, of 264 days, the net registered tonnage passed through the triple system of lockage was nearly 32,000,000 tons, the vessels averaging 1,410 tons; of this tonnage upward of 22,000,000 passed through one of the three locks. In the two months of July and August, the tonnage through the St. Mary's Falls Canal was almost exactly equal to the tonnage through the Suez Canal during the entire previous year, allowance being made for difference in methods of measurement. With a 12 months' season of navigation, the triple lockage system at the St. Mary's Falls Canal would pass 50,000,000 to 60,000,000 tons without serious delay, in vessels of the present average tonnage. If the average tonnage were doubled, making it equal to that of ships now using the Suez Canal, the capacity would be considerably greater. The most sanguine promoter of an Isthmian Canal would not expect this total to be reached in that waterway for a long time to come.

A second lesson is that a canal with locks operated carefully is a safe waterway, as far as the locks are concerned. It is not necessary to give the space to this consideration that its importance seems to warrant, for the proof can be summed in a single sentence. During the 48 years since the opening of the St. Mary's Falls Canal to navigation the stoppages at locks have probably not averaged two days per year, or one day for 3,000,000 tons passed. With locks in duplicate, the stoppages of navigation are almost nil.

The third lesson is the importance of a wide channel The unfortunately narrow width adopted for the Suez Canal, only about half that originally intended, but made necessary to prevent the cost exceeding twice the estimate, has been a harmful precedent. It has been increased there, and will, doubtless, be further increased as traffic increases. In the channels connecting the Great Lakes, where 300 ft. width was generally first adopted for the 20-ft. navigation, the width is being increased to 600 ft. or more, and the principle is adopted that the width of channel should be greater than the length of the largest ship. This principle may be considered applicable generally where currents are strong, the traffic great, and the cutting not too deep.

The improvement of the navigated channels has been accompanied by corresponding developments in the dimensions and character of vessels. Before 1870 the greater part of the freight movement was in sailing vessels carrying 300 to 600 tons. In 1872 appeared the first of a new type, consisting of fleets of two or more vessels, one propelled by steam towing the others, except when compelled by stress of weather to cast off lines. The vessels towed, called tow-barges, were sailing ships not fully rigged, but they could take care of themselves in a storm. The first of these were of 600 to 1,100 tons, net register, carrying in freight about twice the registered tonnage. As the opening of the 16-ft. channel drew near, larger vessels were built, and when that depth became available, in 1884, a great many of 1,500 to 1,900 tons, net register, were in use. The increase was most marked in steam vessels. Up to this time, and for several years thereafter, while grain was the largest item of freight and Lake Michigan ports were the principal shipping points, the largest steamers were employed between Lake Michigan and Lake Erie. By 1888, iron ore had become the leading article, and from that time the vessels built for that trade were larger in tonnage and number than those for any other. During the period from 1888 to 1891, inclusive, the ruling type of freight vessel turned out from the shipyards was of 1,500 to nearly 2,000 tons, net register, carrying 3,000 to 4,000 tons on a draft of 14 to 15 ft. Few sailing vessels or tow-barges were built during this period, except in a single class, the well-known "whale-backs," more generally called "pigs," which, when fully laden, they much resemble. The first of these appeared in 1889. They ran in fleets, one steamer towing one or more barges. They were economical to build and were great carriers, but have not proved altogether successful, and no more are building. By 1892 the preponderance of iron ore, as the leading article of Lake commerce, had become established, and from that year the building of ships for this trade has been the leading feature of Lake ship building. The near approach of a 20-ft. navigation stimulated each year the building of larger ships. More than half the tonnage of freight-carrying vessels built in 1896, when the last American lock was opened to navigation, was in ships exceeding 2,000 tons, net register. Six years before, not a single vessel of this tonnage was in service. The largest vessels yet put in service were built in 1900. Their net registered tonnage is about 4,500 each, but they carry nearly twice their net register. They are 498 ft. long, over all, and of 52 ft. beam. During the last three years there has been a marked tendency to smaller dimensions, but contracts are now placed for still larger vessels. The building of sailing ships has practically ceased. The tonnage built on the Lakes during 1902 was 158,230 tons in 104 vessels, an average of 1,521 tons; while that on the Atlantic and Gulf Coasts was 214,538 tons in 856 vessels, an average of 251 tons, or about one-sixth as much. A comparison of steel steam vessels is perhaps more just. Such a comparison shows: For the Lakes, 44 ships of 152,267 total tonnage, or an average of 3,461 tons; and for the seaboard, 62 ships of 128,751 tons, or an average of 2,076, the Lake tonnage being 18% greater in amount and the vessels 66% greater in average capacity.* The total tonnage on the Lakes is a little more than one-third of the total of that of the United States.

The freight on the Lakes consists mainly of a few items, and facilities for handling them have reached a greater degree of efficiency than anywhere else. Iron ore is loaded from pockets in lofty piers and falls directly into the hold of the ship. The ore piers have now a storage capacity of nearly 1,000,000 tons. During the last season a ship received its full load of 5,280 tons in 68 minutes, through 19 hatches. The equipment for unloading is almost equally perfect, a cargo of 5,300 tons having been unloaded in 3 hours and 45 minutes. Coal is loaded from cars at the rate of 1,000 tons per hour. The use of elevators in loading and unloading grain, mainly a development of Lake commerce, is too well known to need further reference.

It should not be understood that these periods represent averages, or define the stay in ports. Ore-carrying ships require from one-half to one day in the receiving port and about three days in the discharging port, getting a dock and unloading; coal-carrying ships require about one day more at each end of the route. Grain ships require about one day in the receiving port and two in the discharging port.* There is still room for improvement in port facilities.

The most remarkable feature of Lake commerce is the marvelous development of the mining and shipment of iron ore. In 1888 it exceeded 5,000,000 tons for the first time. It doubled in the next seven years and again doubled in the next six years, passing 20,500,000 tons in 1901. In that year the Lake Superior mines furnished 74% of the entire amount produced in the United States. In 1902 the output was increased by 7,000,000 tons, making a total of 27,500,000 tons, which was equal to the total output during the 30 years from the first shipment to 1885, while the increase alone was greater than the entire output of any year previous to 1889. While the output in the United States at large doubled between the years 1888 and 1901, the production of the Lake Superior mines quadrupled during the same period, furnishing nearly all the increase in the ore production of the country.

This wonderful development of a few leading articles of freight has resulted in cheaper transportation than known elsewhere, except on long ocean routes. The most reliable and complete data existing are obtained at the St. Mary's Falls Canals by the co-operation of the governments of Canada and the United States. The average freight rate on all classes of freight during 1902 was 0.89 mill per ton-mile, the average haul being 827.4 miles. If the freight had been carried by rail the average rate could hardly have been less than 3 mills per ton-mile, and the average haul would have been about the same as by water. On this basis the saving in transportation by the water route during one year was upwards of $76,000,000. This amount of saving on Lake Superior commerce alone, during a single year, is greater by $8,000,000 than the entire amount appropriated by the United States for all harbors and waterways on the Lakes above Niagara Falls from the formation of the Government. Indeed, the saving during one year on a single article, iron ore, would repay all the money expended up to this time on the waterways and harbors which it traverses on its way from mine to furnace. Viewed in this way, no great investment was ever made by a corporation or government with such a magnificent showing of profit. But a far broader view may be taken justly; this water route has not merely afforded a saving in expense of transportation, but has been creative of a large part of the wealth of the nation. Without it the development of our manufactures of iron and steel and other industries dependent on them or related to them, all constituting a great share of the national wealth, would have been retarded or impracticable; without it the prairies of the Northwest would have remained unproductive and unpeopled for a much longer time. With these broad considerations in view we may place to the credit of Lake transportation a sum perhaps hardly definable, but compared to which the largest above mentioned is a mere trifle.

It must not be assumed that the minimum freight rates for a 20-ft. navigation have yet been reached. Taking iron ore as an example, the average rate for the year 1902, 0.68 mill per ton-mile, was based on unusually high expenses for labor and other items; moreover, the full channel depth, provided for under the present project for harbor and channel improvements, is not yet fully attained. In the Detroit River the average limiting depth is only 19 ft., instead of 20 ft., as intended. The addition of another foot will permit an increase of cargo, in the largest ships, of about 10%, with little increase in cost of transportation. With normal expenses, larger cargoes and further improvements of terminal facilities, a large reduction of freight charges will be certain to occur.

From the study of Lake navigation some general principles governing cheap transportation may be deduced, which will be applicable to other places.

1. For the cheapest water transportation there must be adequate depth in the channels, so that large ships can be used. Freight rates on iron ores from Lake Superior to Lake Erie ports were, during prosperous years, about $2 per ton when the limiting depth was 15 ft. and less than $1 with the present limiting depth of 19 ft.

2. There must be adequate facilities for handling cargo, so that the delay in port may be reduced to a minimum.

*Rept. Committee on N. Y. State Canals, 1899.

*"Marine Review," Jan. 8, 1903.

*Information in regard to delay in ports was furnished by Captain George P. McKay, Treasurer, Lake Carriers' Association; and by the Editor of the "Marine Review."

The Lake ports have probably the best facilities existing anywhere, and these are important factors in the low freight rates which obtain, nothwithstanding the facts that the vessels lie up four or five months during the year, and, during the season of navigation, make short voyages compared with sea-going ships. Ore-carrying ships make 20 to 24 round trips during the season of seven to eight months, or a mileage of 32,000 to 40,000 miles. The average speeds are 10 to 12 miles per hour. During the last season a ship of somewhat higher speed made 45,340 miles.

3. Different classes of freight require different rates of speed. Lake ships carrying package freight, some of it perishable, some of high value, run 12 to 14 miles per hour, but for those carrying ore a speed of 10 to 12 miles has been found more economical, conforming closely to the usual speed of tramp ships on salt water.

4. Trans-shipment must be avoided as far as possible. The Erie Canal, with its 7-ft. navigation and trans-shipment at Buffalo, has shown a steadily decreasing business in the transportation of vegetable foods, and in 1900 carried only one-third as much as 1869, and only one-fifth of the amount in the maximum year, 1880. The Welland Canal has barely held its own during the same period, although its depth has been increased from 9 to 14 ft. The New York Central and Erie Railroads increased their tonnage in this class of freight six times during the same period. The 14-ft. navigation of the St. Lawrence to Montreal, completing this navigation from the Lakes to tidewater and to sea-going ships, has been opened too recently to predict its consequences safely. It still lacks the necessary terminal facilities at Montreal, but neither this lack, nor the hazardous navigation of the Lower St. Lawrence, from Montreal to the Atlantic, has prevented a great increase in the receipts of grain at Montreal by rail.

5. The prime requisite, after all, for cheap transportation is the existence of great natural resources in the tributary districts. So much misleading discussion of the benefits of water routes has been indulged in, in recent years; such broad inferences have been drawn from the traffic through the St. Mary's Falls Canal as to results to be expected from the opening of other waterways, that it seems necessary to state this truism seriously. The freight tonnage through these canals consists almost entirely of a few articles; first of these is iron ore, which in 1902 was 67% of the total; next is coal, 13%; then flour and grain, 10%; then lumber, 6%; these four articles making 96% of the total. In the natural course of events the iron ore and lumber will be exhausted; but for their accidental and temporary existence, the traffic would not be more than 27% of its present amount; and doubtless even less than this because the development of these two articles has powerfully promoted the development of others. The lumber shipments will soon diminish and before many years will practically cease. Ore shipments will reach a much higher amount than the present before the decline, which is inevitable, sets in. In the meantime the shipments of coal and of agricultural and manufactured products will increase, and, possibly, after the exhaustion of the ores the traffic may remain as large as at present or even become much greater. However this may be, it is clear the present development is due to a combination of agricultural and mineral resources not found anywhere else in the world, and to a spirit of daring enterprise and restless energy hardly paralleled in the history of industrial effort.

A SMALL MUNICIPAL WATER AND ELECTRIC LIGHT PLANT AT TULLAHOMA, TENN.

A combined water and electric light plant, costing only $39,486, was put in operation at Tullahoma, Tenn., in September, 1902. The price named does not include the cost of a hydro-electric power plant, but it does cover a long transmission line to deliver current for light and for pumping. These works were built by the town of Tullahoma, which had a population of 2,684 in 1900, and 2,439 in 1890. In June, 1901, the town voted $35,000 in bonds for a water and light plant, and later it engaged Mr. Granberry Jackson, now of Jackson & Omberg, Memphis, Tenn., as engineer. This article is based on a paper by Mr. Jackson, published in the Proceedings of the Engineering Association of the South (Vol. XIV., No. 1, Dec.—Feb., 1902-3).

Plans for a steam power pumping plant were begun, but were abandoned on receiving a proposition for electric power from the water and light commissioners of Winchester. The latter municipality was, at the time, building a hydro-electric power plant on Elk River, with Mr. Hamilton Johnson, of, Kirkpatrick & Johnson, Jackson, Miss., as engineers. This plant is located at a loop in the river, where, after a flow of several miles, the river approaches within 75 ft. of its original course, with a difference of nearly 8 ft. in the natural low water level. By building a concrete dam, 122 ft. long, 17.8 ft. high, 4 ft. wide at the top and 13 ft. wide at the bottom, and by cutting a canal through the rock separating the two channels, a head of 19½ ft., maximum, and 13 ft. minimum, was obtained. Three 30-in. vertical turbines, with water-wheel governor of the compensating type, were installed, with a total capacity of 400 HP. A minimum of 170 HP. throughout the 24 hours is available, and by means of 10-hour runs and pondage this can be materially increased. The cost of the water power plant built by Winchester was some $13,600. The cost of the electrical equipment at this station is not given, but there have been provided two 100-KW., three-phase, alternating current generators, belted separately to two pulleys, on a horizontal shaft connected with the three turbines. The current is delivered to the switch-board at 2,300 volts. It is transmitted four miles to Winchester at the same voltage, and 10½ miles to the Tullahoma sub-station at 10,000 volts. The latter town takes the current at the Winchester switch-boards, paying $100 a month for all it needs to run its pumps, and to supply an equivalent of 1,250 16-c. p. incandescent lamps, all in excess of that number to be paid for at the rate of 10 cts. per month each.

At the Winchester station the town of Tullahoma put in three 35-KW. oil-cooled transformers. Lightning arresters are provided at each end of the Tullahoma transmission line. The latter is carried by 25-ft. red cedar poles, 40 to the mile. One wire is placed at either end of a standard cross-arm, and one on a pin set in the top of the pole. Glass insulators were used. The three wires are of No. 6 bare copper.

The substation at Tullahoma is a 20 × 30-ft. brick building, in which is an oil switch, from which the wires lead to step-down transformers in a separate building. There are six transformers. Three are of 20-KW., reducing the current to 2,300 volts, for two incandescent lighting circuits, and for one constant-current transformer for 30 series inclosed arc street lamps. The other three transformers are of 20 KW., and reduce the voltage to 200. There are two 50-HP. induction motors, one of which drives the compressor for the air-lift pump, while the other drives a triplex pump with a daily capacity of 750,000 gallons. Provision is made for lighting the substation.

The water supply for the town is taken from two 8-in. wells, near the station. The wells are about 80 ft. apart (too close, it proves), some 200 ft. deep, and about 80 ft. in rock. Water was struck at about 120 ft., and rose, naturally, to within about 45 ft. of the surface. The wells were cased to form a seal with the rock. For the air-lifts, 2-in. pipes were placed in 5-in. discharge pipes, both pipes being of galvanized iron. The air nozzles were made of brass, discharging the air spirally upwards through 30 ¼-in. holes to each nozzle. A test of the two wells showed a combined yield of 25,000 gallons an hour.

The water from the wells is discharged into an 80,000-gallon covered brick reservoir, 30 ft. in diameter and 15 ft. deep. From this reservoir the 750,000-gallon pump delivers water to a 75,000 gallon elevated steel tank, with hemispherical bottom and conical roof, mounted on a steel tower. The top of the tank proper is 120 ft. above the capstones on which the four supporting steel columns rest. The plates of the tank are ¼ and 5-16-in. thick. The columns are composed of 12-in., 30-lb., channels, and the tower is divided into four stories by means of horizontal struts of 7-in. channels, laced together. Diagonal tension rods are provided at each side of each story. The four concrete pillars beneath the columns are 4½ ft. square on their upper, and 9½ ft. square on their lower faces, and 5½ ft. deep. They are surmounted by concrete capstones 3 ft. square and 18 ins. deep. A 2½-in. anchor bolt extends to within 6 ins. of the bottom of each pillar, where it is attached to a heavy plate. Portland cement was used for the concrete.

There are about six miles of 4, 6, and 8-in. standard cast-iron pipe, and 51 double-nozzle hydrants.

The cost of the various parts of these works was as follows: Pipe, valves, and hydrants, $13,240; tower and tank, $3,995; electrical apparatus, $6,257; transmission line and other electrical construction, $7,628; wells, $1,250; air-lift plant, $2,000; triplex pump, $1,550; reservoir, $948; buildings, $738; engineering and superintendence, $1,880; total, $39,486.

As stated, the plant was put in operation in September, 1902. For the month of January, 1902, the revenue was as follows: 700 16-c. p. lamps, flat rate, $266; 146 16-c. p. lamps, meter rate, $34; 22 water-takers, $38; total, $338.

The operating expenses for the same month were: Superintendant, $75; assistant, $20; power, $100; carbons, globes and incidentals, $10; total, $205. If to this is added interest at the rate of 4½%, and depreciation at 5%, or $317, there results a total expense of $521, or, deducting revenue, $184 for 30 arc lamps (c. p. not given) and 51 fire hydrants. At $75 per year for lights and $50 for hydrants, the charges paid a private company for the same service would have been $4,800.

The meter rates for lighting are 12 cts. per KW.-hr. In terms of lamps per month the metered services, in January, paid 23.1 cts., and the flat rate services, 38 cts.

ACCIDENTS DUE TO COMBUSTION WITHIN AIR COMPRESSORS.*

By W. L. Saunders, M. Am. Soc. C. E.

Dr. Ledoux gives an interesting account of a serious accident which might occur in almost any mining plant provided due precautions are not observed. In the first place, it is very likely, though not stated, that the air compressor in question was not a compound machine; that is, the air was not compressed in stages. This is the first point to consider when equipping a mine with an air compressor, and where the purchaser wishes to be insured against a similar occurrence. By compressing the air in stages, that is, by the use of compound cylinders, the maximum temperature during compression is very much reduced and the liability to "flaming" is less. Having an air compressor with compound cylinders, the next thing to do is to provide a high grade of oil to be used in the cylinders. This should be an oil with a high flashing point and of a non-coking nature. In other words, when the oil is placed on a shovel and held over a fire there should be little or no carbon deposit left after it has been volatilized. The third point to be observed is to caution the engineer not to use much oil in the air cylinders. A drop every five minutes is sufficient in a cylinder of ordinary size, and every engineer should feed soapsuds into the cylinders at least one day in the week in order to wash away any deposit which may have accumulated through the use of oil which has been acted upon by highly-heated air. The soapsuds may be fed through the regular oil cup. Care should be taken not to let the machine lie idle with soapsuds remaining in it; that is, shortly before quitting time the feeding of soapsuds should be stopped and oil feeding substituted.

Another point is that every engineer should look into the discharge valves, air receiver and other places where deposits are liable to accummulate, and keep them clean. A discharge valve which sticks, either through defective construction or through the accumulation of carbon around it, is liable to admit hot compressed air from the receiver back into the cylinder and increase by so much the temperature of the air to be compressed, so as possibly to reach the flashing point of the oil. In connection with this, it is well, also, to bear in mind that the intake air should come from the outside and not from the inside of the engine room. This is important, because a cold intake gives a higher volumetric efficiency to the compressor, and, also, because it results in a lower maximum temperature during compression, which not only means safety against "flaming," but economy of power. The hoter the air is during compression, the greater is the resistance to compression. Another reason for an outside intake is that bad air in the engine room, or smoke or fumes from a fire, will not be sucked into the compressor and discharged into the mine.

This case also illustrates the value of inter-coolers and after-coolers in a compressed-air plant. These coolers are surface condensers, the inter-cooler being placed between the high and low-pressure air cylinders, and serving to reduce the temperature between the two stages of compression. The after-cooler reduces the temperature after the last stage, and condenses and collects all such foreign matter as oil, moisture, dust, etc., sending pure, dry air down into the mine.

THE PRODUCTION OF PORTLAND CEMENT in the U. S. for 1902 was 16,875,506 barrels, according to an estimate prepared by the Division of Mining and Mineral Resources of the U. S. Geological Survey. The natural cement production was 9,083,759 barrels, and of slag cement 478,555 barrels. The total gain in production over 1901 is more than 30%. In 1892 only 547,440 barrels of Portland, as against 8,211,181 of natural cement, were produced.

*From the "Transactions of the American Institute of Mining Engineers in discussion of Dr. A. R. Ledoux's paper (Eng. News, April 9, p. 321).